DOCUMENT RESUME

ED 157 685 SE 023 048

AUTHOR Harmon, David Jerome
TITLE The Relationships of Student Anxiety and Dependency to the Effects of Teaching Structure on the Learning of Science Knowledge and Processes Within Inductive/Discovery Learning.
PUB DATE 77
NOTE 258p.; Ph.D. Dissertation, The Ohio State University

EDRS PRICE MF-$0.83 HC-$14.05 Plus Postage.
DESCRIPTORS *Anxiety; Discovery Learning; *Doctoral Theses; *Educational Research; Elementary Education; *Elementary School Science; Formative Evaluation; Instruction; Knowledge Level; *Science Education; *Teaching Methods

ABSTRACT

This study was designed to determine the relationships of student anxiety and dependency to the effects of teaching structure on the acquisition of science knowledge and processes within inductive/discovery learning. Teaching structure refers to the relative amounts of teacher and/or student control within the tasks. Randomly assigned fifth- and sixth-grade students from two elementary schools within one suburban school district comprised the population. Instruments used included the Children's Manifest Anxiety Scale, the Modified Dependence Proneness Scale, and the Ankney-Joyce Reasoning Test. Results support the following conclusions relative to the population sampled in this study: (1) The high anxiety individuals gain more knowledge when teaching is highly structured; (2) Contrary to the literature, low teaching structure enhanced low anxiety students' performance relative to that of the high anxiety students; (3) There is some evidence that low dependent individuals perform better with low teaching structure; (4) Individuals who are both high in anxiety and high in dependency do better on the knowledge and process levels of achievement; (5) Overall, low dependency individuals do better on more complex tasks; and (6) Overall, a high degree of teaching structure is better for difficult tasks. (Author/MA)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED157685

THE RELATIONSHIPS OF STUDENT ANXIETY AND DEPENDENCY TO THE EFFECTS OF TEACHING STRUCTURE ON THE LEARNING OF SCIENCE KNOWLEDGE AND PROCESSES WITHIN INDUCTIVE/DISCOVERY LEARNING

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

David Harmon

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM"

By

David Jerome Harmon, Ph.D.

The Ohio State University, 1977

Dr. Stanley L. Helgeson, Adviser

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

Researchers are becoming more amenable to the notion of aptitude-treatment-interaction (ATI) as opposed to the search for the one "best" method or instructional treatment. This study was designed to determine the relationships of student anxiety and dependency to the effects of teaching structure on the acquisition of science knowledge and processes within inductive/discovery learning.

Five correlational concepts from within the conceptual scheme--force--constituted the science content of the instructional tasks. Worksheets were used to vary teaching structure within each of five instructional periods (one task/period). Teaching structure refers to the relative amounts of teacher and/or student control within the tasks. The treatments were developed from existing laboratory procedures. Knowledge and processes level criteria were

SE 023 048

used to measure the effects of teaching structure. Knowledge level criteria were one posttest for each concept and the composite of the five posttests. Process measures included inferring, predicting, interpreting data, and identifying and controlling variables and the composite of the four scales. The range of KR20 values was .55 to .91 for the knowledge and process measures.

The population was comprised of all fifth and sixth grade students from two elementary schools within one suburban school district. The sample (168) was stratified on scores from the Children's Manifest Anxiety Scale and the Modified Dependence Proneness Scale and the students randomly assigned to the six treatment groups. A pretest analysis showed that the use of the Ankney-Joyce Reasoning Test scores as a covariate reduced personality group differences in knowledge and process level concept understanding which existed prior to treatment.

The data were analyzed using multivariate analysis of covariance. A significant multivariate first order interaction resulted between the treatments and anxiety with the five knowledge level posttests. Significant univariate first order interactions resulted between: (1) the treatments and anxiety with the knowledge posttest for Task 1 (Height Affects Impact Force); (2) the treatments and dependency with the knowledge and process total measures and the identifying and controlling variables subscale; and (3) anxiety and dependency with the knowledge and process total measures, knowledge posttest for Task 2 (Weight Affects Speed), and the process subscales of inferring and identifying and controlling variables. Significant main effects resulted

between: (1) levels of teaching structure with the knowledge posttest for Task 3 (Mass Affects Motion); and (2) levels of dependency with the knowledge posttest for Task 4 (Mass Affects Momentum).

The results support the following conclusions relative to the population sampled in this study.

1. The high anxiety individuals gain more knowledge when teaching is highly structured.

2. The literature and this study are contradictory for the influence of teaching structure on the learning of knowledge by individuals of high anixety versus low anxiety. In this study, low teaching structure enhanced low anxiety students' performance relative to that of the high anxiety students. The literature suggested the opposite.

3. There is some evidence that low dependent individuals perform better with low teaching structure.

4. The person who is both high in anxiety and high in dependency does better on both the knowledge and process levels of achievement.

5. Overall, low dependency individuals do better on more complex tasks.

6. Overall, a high degree of teaching structure is better for difficult tasks.

THE RELATIONSHIPS OF STUDENT ANXIETY AND DEPENDENCY TO THE EFFECTS OF TEACHING STRUCTURE ON THE LEARNING OF SCIENCE KNOWLEDGE AND PROCESSES WITHIN INDUCTIVE/DISCOVERY LEARNING

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

David Jerome Harmon, B.S., M.A.

*****

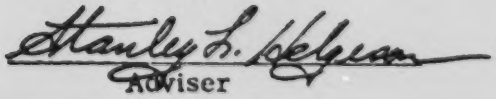
The Ohio State University

1977

Approved By

Reading Committee:

Stanley L. Helgeson
Patricia E. Blosser
Arthur L. White
James K. Duncan



Adviser
Faculty of Science and Mathematics Education

ACKNOWLEDGEMENTS

I am deeply grateful to all the people who made this study possible by providing the foundation for its conception and for the help and encouragement in bringing it to completion. It is with great pleasure that I acknowledge Professors Stanley L. Helgeson and Patricia E. Blosser, who have provided patient and untiring assistance throughout my doctoral program. Both have provided wise and sympathetic advice during trying times.

I am particularly grateful to Professor Arthur L. White, who has shown tremendous insight and assistance in the design, analysis and synthesis of this research. Professor James K. Duncan has provided much encouragement throughout this study.

The administrators, teachers and students of three elementary schools have been particularly helpful in providing a cooperative atmosphere for data collection.

However, this project would not have been completed without the support of my wife. My deepest thanks goes to my wife, Judy, who has contributed typing, editorial expertise, patience, understanding and love during times that seemed impossible to us both.

VITA

July 27, 1947	Born--Charleston, West Virginia
1969	B. S., West Virginia Institute of Technology, Montgomery, West Virginia
1969-1974	Teacher, Kanawha County Schools, Charleston, West Virginia
1971	M. A., Ball State University, Muncie, Indiana
1974-1976	Research Associate, The Center for Vocational Education, The Ohio State University, Columbus, Ohio
1976-1977	Teaching Associate, Faculty of Science and Mathematics Education, The Ohio State University, Columbus, Ohio

FIELDS OF STUDY

Major Field: Science Education. Professors Stanley L. Helgeson, Patricia E. Blosser, and Arthur L. White

Minor Field: Botany and Ecology, Professor Clarence E. Taft

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
VITA	iii
LIST OF TABLES	vi
LIST OF FIGURES	xiv
Chapter	
I. INTRODUCTION	1
Need for Study	1
The Problem	4
Hypotheses	4
Assumptions	5
Delimitations	6
Limitations	7
Definition of Terms	7
II. REVIEW OF RELATED LITERATURE	10
Characteristics of Aptitude-Treatment-Interaction	11
Personological Characteristics	12
Concept Studies	16
Inductive/Discovery Learning	23
Summary	28
III. METHODS AND PROCEDURES	31
Instructional Task Development	31
Science Content	33
Treatments	36
Variables and Instruments	38
Pilot Study	46
Site Selection and Sampling (Main Study)	49
Data Gathering and Analysis	51

Page

IV. RESULTS OF THE STUDY 55

Support for Covariate Use 57
Descriptive Data--Anxiety and Dependency Measures . . . 68
MANCOVA Results. 78

V. SUMMARY, DISCUSSION OF RESULTS, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS. 118

Summary of the Study. 118
Discussion of Results. 121
Conclusions 128
Implications 129
Recommendations for Future Study. 131

BIBLIOGRAPHY 134

APPENDIX

A 148

B 174

C 191

D 194

E 196

F 206

LIST OF TABLES

Table		Page
1.	Six Levels of Teaching Structure	37
2.	Summary of Item Analyses for Measures of Low Level Concept Understanding	42
3.	Summary of Item Analyses for Measures of High Level Concept Understanding	44
4.	Analysis of Variance of Equipment Manipulation Scores by Instructional Treatment	47
5.	Analysis of Variance of Knowledge of Concept Components by Personality Groups	48
6.	Analysis of Variance of Science Processes Understanding by Personality Groups	49
7.	Distribution of the Subjects of the Study	50
8.	Data Analysis Diagram	51
9.	Correlations with the Covariate and the Dependent Variables	58
10.	MANOVA for Anxiety by Dependency Interactions with Five Dependent Variables: Four Science Process Subscores and Knowledge Pretest Scores, and for Anxiety by Dependency with Total Science Process Scores	60
11.	Raw Cell Means of Identifying and Controlling Variables Pretest for Anxiety by Dependency Interaction	61
12.	MANCOVA for Anxiety by Dependency Interactions with Five Dependent Variables: Four Science Process Subscores and Knowledge Pretest Scores and for Anxiety by Dependency with Total Science Process Scores	62

Table		Page
13.	Adjusted Cell Means of Identifying and Controlling Variables for Anxiety by Dependency Interaction	63
14.	Summary of MANOVA for Anxiety and Dependency Main Effects with Five Dependent Variables: Four Science Process Subscores and Knowledge Pretest Scores, and for Anxiety and Dependency with Total Science Process Scores	64
15.	Summary of MANOVA Dependency Main Effects: Raw Cell Means for Inferring and Science Process Total	65
16.	Summary of MANCOVA for Anxiety and Dependency Main Effects with Five Dependent Variables: Four Science Process Subscores, Knowledge Pretest Scores, and for Anxiety and Dependency with Total Science Process Scores	66
17.	Summary of MANCOVA Dependency Main Effects: Adjusted Cell Means for Inferring and Science Process Total	67
18.	Group Statistics--Anxiety Scale	69
19.	Analysis of Variance of Anxiety Scores by Anxiety, Dependency and Treatments	70
20	Means and Standard Deviations of Anxiety Scores by Anxiety, Dependency and Treatments and Anxiety by Dependency Level Means	71
21.	Means of Anxiety Scores for Anxiety and Dependency Main Effects	72
22.	Summary of Means of Anxiety Scores: Within Structure, Anxiety by Structure, and Dependency by Structure Contrasts	73
23.	Group Statistics--Dependency Scale	74

Table		Page
24.	Analysis of Variance of Dependency Scores by Anxiety, Dependency, and Treatments	74
25.	Means and Standard Deviations of Dependency Scores by Anxiety, Dependency and Treatments and Anxiety by Dependency Level Means	75
26.	Means of Dependency Scores by Dependency and Treatments	76
27.	Means of Dependency Scores for Anxiety and Dependency Main Effects	77
28.	Summary of Means of Dependency Scores: Within Structure and Anxiety by Structure Contrasts	78
29.	Test of Equality of Regression in all Cells: Variables Were Science Process and Knowledge Total Scores	79
30.	Test of Equality of Regression in all Cells: Variables Were the Five Knowledge Level Posttests	80
31.	Test of Equality of Regression in all Cells: Variables Were the Four Science Process Subscores	80
32.	Test of Treatment by Anxiety Interactions with Five Knowledge Posttests Scores	82
33.	Treatment by Anxiety (HA-LA) Adjusted Cell Means for the Five Knowledge Posttests	83
34.	Anxiety by Treatment Standardized Discriminant Function Coefficients for the Five Knowledge Posttests	84
35.	Anxiety by Treatment Standardized Discriminant Function Means with Tasks One through Four Considered in Combination	85
36.	Test of Treatment by Dependency Interactions with the Total Knowledge and Process Scores	89
37.	Treatment by Dependency Adjusted Cell Means for Knowledge Total	90

Table		Page
38.	Test of Anxiety by Dependency Interactions with Total Knowledge and Process Scores	92
39.	Test of Anxiety by Dependency Interactions with the Five Knowledge Level Posttest Scores	93
40.	Anxiety by Dependency Adjusted Cell Means for Knowledge Total	94
41.	Anxiety by Dependency Adjusted Cell Means for Knowledge Posttest Task 2 (Weight Affects Speed)	94
42.	Anxiety by Dependency Adjusted Cell Means for Knowledge Posttest Task 3 (Mass Affects Motion)	96
43.	Test of Treatment by Dependency Interactions with the Four Science Process Subscale Scores	97
44.	Treatment by Dependency Adjusted Cell Means for Process Total	98
45.	Treatment by Dependency Adjusted Cell Means for the Science Process Skill--Identifying and Controlling Variables	100
46.	Test of Anxiety by Dependency Interactions with the Four Science Process Subscale Scores	102
47.	Anxiety by Dependency Adjusted Cell Means for Process Total	103
48.	Anxiety by Dependency Adjusted Cell Means for Inferring	105
49.	Anxiety by Dependency Adjusted Cell Means for Identifying and Controlling Variables	108
50.	Test of Dependency Main Effects with the Five Knowledge Level Posttests	111
51.	Adjusted Means of Task 4 (Mass Affects Momentum) Posttest Scores by Dependency Groups	112
52.	Test of Treatment Main Effects with the Five Knowledge Level Posttests	113

Table		Page
53.	Adjusted Mean Comparison Matrix of Task 3 (Mass Affects Motion) Posttest Scores by Treatment Groups	114
54.	Summary of Main Study MANCOVA Results	115
55.	Test Item Analyses	195
56.	Anxiety by Dependency Adjusted, Raw Means and Raw Standard Deviations for Pretest Variables	207
57.	Raw and Adjusted Means for Anxiety and Dependency Main Effects with Pretest Variables	208
58.	MANCOVA for Treatment by Anxiety by Dependency with Knowledge and Process Totals	209
59.	MANCOVA for Treatment by Anxiety by Dependency with Five Knowledge Posttests	209
60.	MANCOVA for Treatment by Anxiety by Dependency with Four Process Subscales	210
61.	MANOVA for Treatment by Anxiety by Dependency with Knowledge and Process Totals	210
62.	MANOVA for Treatment by Anxiety by Dependency with Five Knowledge Posttests	211
63.	MANOVA for Treatment by Anxiety by Dependency with Four Process Subscales	211
64.	Adjusted Means for Treatment by Anxiety by Dependency with the Eleven Main Study Dependent Variables	212
65.	Raw Means and Standard Deviations for Treatment by Anxiety by Dependency with the Eleven Main Study Dependent Variables	213
66.	MANCOVA for Treatment by Anxiety with Knowledge and Process Totals	215

Table		Page
67.	MANCOVA for Treatment by Anxiety with the Four Process Subscales	215
68.	MANCOVA for Treatment by Dependency with the Five Knowledge Posttests	216
69.	MANOVA for Treatment by Anxiety with Knowledge and Process Totals	216
70.	MANOVA for Treatment by Anxiety with the Five Knowledge Posttests	217
71.	MANOVA for Treatment by Anxiety with the Four Process Subscales	217
72.	MANOVA for Treatment by Dependency with Knowledge and Process Totals	218
73.	MANOVA for Treatment by Dependency with the Five Knowledge Posttests	218
74.	MANOVA for Treatment by Dependency with the Four Process Subscales	219
75.	MANOVA for Anxiety by Dependency with Knowledge and Process Totals	219
76.	MANOVA for Anxiety by Dependency with the Five Knowledge Posttests	220
77.	MANOVA for Anxiety by Dependency with the Four Process Subscales	220
78.	Adjusted Means for Treatment (A-F) by Anxiety with Six Main Study Dependent Variables	221
79.	Raw Means for Treatment (A-F) by Anxiety with the Eleven Main Study Dependent Variables	222
80.	Adjusted Means for Treatment (A-F) by Dependency with Eight Main Study Dependent Variables	223
81.	Raw Means for Treatment (A-F) by Dependency with the Eleven Main Study Dependent Variables	224

Table		Page
82.	Adjusted Means for Anxiety by Dependency with Five Main Study Dependent Variables	225
83.	Raw Means for Anxiety by Dependency with the Eleven Main Study Dependent Variables	226
84.	MANCOVA for Treatment Main Effects with Knowledge and Process Totals	227
85.	MANCOVA for Treatment Main Effects with the Four Process Subscales	227
86.	MANCOVA for Anxiety Main Effects with Knowledge and Process Totals	228
87.	MANCOVA for Anxiety Main Effects with Five Knowledge Posttests	228
88.	MANCOVA for Anxiety Main Effects with the Four Process Subscales	229
89.	MANCOVA for Dependency Main Effects with Knowledge and Process Totals	229
90.	MANCOVA for Dependency Main Effects with Four Process Subscales	230
91.	MANOVA for Treatment Main Effects with Knowledge and Process Totals	230
92.	MANOVA for Treatment Main Effects with Five Knowledge Posttests	231
93.	MANOVA for Treatment Main Effects with Four Process Subscales	231
94.	MANOVA for Anxiety Main Effects with Knowledge and Process Totals	232
95.	MANOVA for Anxiety Main Effects with Five Knowledge Posttests	232
96.	MANOVA for Anxiety Main Effects with Four Process Subscales	233

Table		Page
97.	MANOVA for Dependency Main Effects with Knowledge and Process Totals	233
98.	MANOVA for Dependency Main Effects with Five Knowledge Posttests	234
99.	MANOVA for Dependency Main Effects with Four Process Subscales	234
100.	Adjusted Means for Treatment Main Effects with Ten Main Study Dependent Variables	235
101.	Raw Means for Treatment Main Effects with the Eleven Main Study Dependent Variables	236
102.	Adjusted Means for Anxiety Main Effects with the Eleven Main Study Dependent Variables	237
103.	Raw Means for Anxiety Main Effects with the Eleven Main Study Dependent Variables	238
104.	Adjusted Means for Dependency Main Effects with Ten Main Study Dependent Variables	239
105.	Raw Means for Dependency Main Effects with the Eleven Main Study Dependent Variables	240

LIST OF FIGURES

Figure		Page
1.	Discrimination between Levels of Anxiety at Levels of Teaching Structure for Knowledge Posttests One Through Four in Combination	85
2.	High Anxiety by Treatment Means for the Five Knowledge Posttests	86
3.	Low Anxiety by Treatment Means for the Five Knowledge Posttests	87
4.	Interactive Effect of Treatments and Dependency on Knowledge Total	91
5.	Interactive Effect of Anxiety by Dependency on the Task 2 Knowledge Level Posttest	95
6.	Interactive Effect of Treatment by Dependency on the Total Science Process Measure	99
7.	Interactive Effect of Treatment by Dependency on the Identifying and Controlling Variables Measure	101
8.	Interactive Effect of Anxiety by Dependency with Total Science Process Measure	104
9.	Interactive Effect of Anxiety by Dependency with the Inferring Measure	106
10.	Interactive Effect of Dependency by Anxiety with the Inferring Measure	107
11.	Interactive Effect of Anxiety by Dependency with the Identifying and Controlling Variables Measure	109

CHAPTER I

INTRODUCTION

Need for Study

Researchers are becoming more amenable to the notion of aptitude-treatment-interaction (ATI) as opposed to the search for the one "best" method or instructional treatment. Egan and Greeno (1973), Koran (1971), Kline (1971), Keislar (1962) and other scholars have suggested that no single instructional procedure provides maximal learning for all students. Cronbach and Snow (1969) pointed out that current research supports the position that learning effectiveness is a function of the interaction of instructional treatments and learner characteristics. Salomon (1971, pp. 327-328) cites two functions of ATI: "(1) improving instruction and (2) ... developing better explanatory principles concerning the nature of instruction." Others are emphatic; Mitzel, for example, predicts "an instructional revolution characterized by adaptive education (i.e., the tailoring of subject matter to fit the special requirements and capabilities of each learner)." (1970, p. 436).

Pella (1966) suggests that concept learning is a desired outcome of science instruction. Pella also stated (p. 32) that, "Concepts are important not only because they are the warp and woof of science but also because they provide the possessor with a means of coping with the development of

knowledge in the future." Gagne (1964) identified eight types of learning. Concept learning ranks sixth in terms of complexity.

In regard to individual differences (IDs) and concept learning, Jensen (Klausmeier and Harris, 1966, pp. 140-141) noted:

> ... we must do something about IDs in learning because, like Mt. Everest, they are there. And they loom large in our research on learning; the more complex the type of learning, the more conspicuous and unavoidable are the IDs. If we are to develop a science of learning, we cannot ignore this vast continent of phenomena involving IDs. It is essential grist for our scientific enterprise, and it deserves higher priority in our investigative efforts than it is now receiving.

Crocker, Bartlett and Elliot (1976), Domino (1971), Tuckman (1969) and Flanders (1965) have conducted ATI research which included student dependency as a personological variable. Flanders (1961, p. 575) cited two reasons for being interested in dependence proneness:

> First, we have found that dependent prone students are more sensitive to the behavior of the teacher than are low dependent prone students; therefore, control of this variable is essential in any experiment that compares one method of teaching with another. Second, dependent prone students will probably learn more subject matter when their greater need for supervision and personal support is satisfied; therefore, the identification of such students may be of value to the classroom teacher.

Research conducted by Gaudry and Spielberger (1971) and McCandless and Castaneda (1956) suggests that student anxiety interacts with instructional treatments and affects student achievement. Additional research is needed to determine if the anxiety construct interacts with elementary school science instructional treatments when varying degrees of structure are employed within inductive/discovery learning.

Equivocal findings characterize studies comparing inductive/discovery treatments with more structured (i.e., teacher controlled) treatments. It is conceivable that such methods are each highly effective but for different sub-groups of learners, hence requiring the study of interactions. A second possible explanation for inconsistent research results is differences in treatment conditions labeled inductive/discovery. Tanner (1969), and Thomas and Snider (1969) refer to a highly directed inductive teaching method as guided discovery. Studies by Kline (1971) and Kersh (1958) included treatments designated as self-directed, no teacher direction or independent discovery. Guided and independent discovery treatments typically differ in amount of direction or guidance provided by a teacher.

Induction, discovery, hands-on laboratory experiences, and science processes are common elements in such elementary science curricula as ESS and S-APA. The degree of teacher or student control (i.e., teaching structure) desirable with different types of students is not clearly delineated. The need for this study is enhanced by the complexity of concept learning, and the inconsistent results of inductive/discovery studies.

This study aids in determining the relationship(s) between two specific personological variables, levels of concept understanding, and teaching structure when incorporating inductive/discovery strategies.

The Problem

The major problem was to determine the relationships of student anxiety and dependency to the effects of teaching structure on the acquisition of science knowledge and processes within inductive/discovery learning.

Hypotheses

1. There is a significant three-way interaction in the knowledge level variable between levels of Teaching Structure, levels of Anxiety and levels of Dependency.

2. There is a significant three-way interaction in the science processes level variable between levels of Teaching Structure, levels of Anxiety and levels of Dependency.

3. There are significant two-way interactions in the knowledge level variable between levels of Teaching Structure, levels of Anxiety or levels of Dependency.

4. There are significant two-way interactions in the science processes level variable between levels of Teaching Structure, levels of Anxiety or levels of Dependency.

5. There are significant differences in the means for the knowledge level variable between levels of Anxiety.

6. There are significant differences in the means for the science processes level variable between levels of Anxiety.

7. There are significant differences in the means for the knowledge

level variable between levels of Dependency.

8. There are significant differences in the means for the science processes level variable between levels of Dependency.

9. There are significant differences in the means for the knowledge level variable between levels of Teaching Structure.

10. There are significant differences in the means for the science processes level variable between levels of Teaching Structure.

Assumptions

1. Both the knowledge and science process levels of concept understanding can be assessed using paper and pencil tests.

2. The random assignment of subjects within a class to different treatments and the independent administration of the treatments to each individual justifies the use of the individual as the experimental unit.

3. Differences in subjects' level of expectation were reduced by consistently offering small rewards for participation and high achievement on all measures.

4. Instructional tasks are horizontally organized (Task A is not prerequisite for Task B, etc.).

5. Pretreatment instruction provided by the investigator was at a less abstract level than treatment instruction.

6. The personality of the learner is a relevant variable to be considered in inductive concept learning.

7. Pretreatment understanding of the selected force-related concepts and science processes among the identified personality groups can be reliably measured using paper and pencil tests.

8. The treatments represent a continuum from high to low teaching structure within inductive/discovery teaching.

Delimitations

1. The subjects were from the fifth grade and sixth grade levels.

2. The subjects were from one suburban school district.

3. Academic, social, economic and cultural differences among participating students were distributed equally by randomization rather than identified and measured.

4. The selected concepts were within the conceptual scheme--force.

5. The instructional treatments were restricted to inductive/discovery.

6. The six levels of teaching structure were imposed through the use of worksheets.

7. The personological variables were restricted to high-low levels of Anxiety and high-low levels of Dependency.

8. The constructs included as criteria were: (1) knowledge; and (2) science processes (identifying and controlling variables, interpreting data, predicting and inferring).

9. Concrete reasoning ability was selected as a critical

concommitant variable for use as a covariate if appropriate.

Limitations

1. The number of instructional tasks was limited to five due to time and economic restrictions.

2. The population to which generalizations could be made was limited to fifth and sixth grade students enrolled during the Spring Quarter 1977 in two elementary schools within a suburban community.

Definition of Terms

The following terms or phrases are defined and/or described to provide an understanding of terminology. Additional terms are defined as they appear in the text.

1. Concept. A concept is an abstraction from a series of experiences within an instructional task which defines either a relationship or a class of objects or events. The concept instances have common features. The common features are either sets of relationships or common specific stimuli.

2. Conceptual Scheme. A conceptual scheme is " ... a network of concepts related in a systematic way." (Hurd, 1969, p. 77).

3. Low Level Concept Understanding. This phrase refers to the knowledge level measure and is defined as "little more than the remembering of the idea or phenomenon in a form very close to that in which it was originally encountered." (Bloom, 1956, pp. 28-29).

4. High Level Concept Understanding. This phrase refers to the

science processes measure. The subjects' ability to identify and control variables, interpret data, and make predictions and inferences was assessed within this dependent variable. The rationale for considering science process achievement as a "higher level" of understanding is discussed in detail in Chapter II.

5. Suburban Setting. A residential area adjacent to a city of 500,000 or more inhabitants.

6. Personological Variable. A measure of individual characteristics (e.g., IQ, status, anxiety or scientific interest).

7. Anxiety. A personological construct which implies a disposition to avoid risk of failure to meet personal expectations or the expectations of significant others. In addition, anxiety implies a state of internal tension, stress, and apprehension. Characteristic descriptions of high and low anxious students are given in Chapter II.

8. Dependence Proneness. A personological construct which implies a disposition to meticulously respond to the directions of significant others. In the classroom such students (1) exhibit a strong need for teacher approval and support; and (2) continuously check the work with the teacher to be sure that they are proceeding in a manner consonant with teacher expectations. Characteristic descriptions of high and low dependent students are given in Chapter II.

9. Inductive/Discovery. A teaching/learning strategy that requires the student to form a concept based on his interaction with concept instances.

Each level of the instructional treatment required inductive discovery learning in that the concept(s) were not presented to the learners prior to treatment. Inductive/discovery learning is discussed in detail in Chapter II.

10. Positive Instance. Those stimuli within each instructional task that exemplify or illustrate the concept. Several positive instances in sequence constitute an instructional task.

11. Aptitude. Aptitude is defined as one or more learner traits or characteristics.

12. Teaching Structure. For the purposes of this investigation, teaching structure refers to the relative amounts of teacher and/or student control within each of the five instructional tasks.

CHAPTER II

REVIEW OF RELATED LITERATURE

The review will be divided into four segments. The first will be a discussion of design considerations in Aptitude-Treatment-Interaction studies. The second segment of the review will deal with the student personological variables of anxiety and dependency. Anxiety and dependency will be studied to: (1) find out what specific student characteristics are associated with anxiety and dependence proneness, and (2) see when these characteristics are a factor in achievement.

The third segment deals with: (1) the need for concept studies; (2) characterizations of concepts; and (3) student growth and development influences. Concepts are discussed to identify a level of learning and determine important learner characteristics that may be helpful in instructional task development.

A rationale for considering research within inductive/discovery learning is presented in the fourth segment of this review. The effects of inductive/discovery strategies on student acquisition of science knowledge and processes are of primary concern.

Characteristics of Aptitude-Treatment-Interaction

Design Considerations. The success of an ATI study is largely dependent on the interaction between the personological variables and treatments. Salomon (1971), Shulman (1970) and Cronbach and Gleser (1965) have expressed concern regarding the infrequency of ATI studies resulting in disordinal interactions. Bracht (1970) searched for an explanation for the paucity of experimental findings showing disordinal interactions. The procedure involved investigating the relationship of treatment tasks, personological variables, and dependent variables to the occurrence of ATI. This procedure is discussed below.

Bracht (1970) classified personological variables as either factorially simple or factorially complex based on the number of suspected substantial loadings. If the variable was judged to have substantial loading on only a few factors, it was considered factorially simple. Variables having substantial loading (factor analysis) on many factors constituted the factorially complex category. "Measures of specific abilities, interests, attitudes, personality traits, and social, economic and educational status were classified as factorially simple." (pp. 628-629). Examples of factorially complex variables include general ability (I.Q.) and achievement. The frequency of studies yielding disordinal interaction was greater when factorially simple variables were incorporated. This phenomenon was explained as follows:

> Measures of general ability and achievement correlate substantially with most complex learning tasks and are not likely to correlate differentially with achievement in alternative treatments. Factorially

> simple measures have substantial correlations with performance in only selected cognitive tasks or have relatively low correlations with most measures of complex cognitive achievement. (p. 637)

A second major consideration concerned: (1) the number of personological variables selected; (2) the relationship(s) between the personological variables and treatment success; and (3) the correlation between the personological variables. With regard to these considerations, Bracht suggests:

> ATI is most likely to occur when two personological variables have been included in the experimental design. One personological variable is judged to correlate substantially with success in one treatment and the other is judged to correlate substantially with success in the second treatment. The correlation between the two personological variables must be moderately low or nonsignificant for the disordinal interaction to occur. (p. 639)

Personological Characteristics

Anxiety. Spielberger (Spielberger and Sarason, eds., 1975) reported seven studies which included the Manifest Anxiety Scale (MAS) as the measure of anxiety proneness. Among the findings was that "scores on the MAS seemed to reflect individual differences in the disposition to respond to threats to self-esteem (ego threats) with differential elevations of anxiety." (p. 136) In regard to emotional states, Spielberger (1975) characterized anxiety as subjective, consciously perceived feelings of tension, apprehension and nervousness.

Eugene Levitt (1967) has worked extensively with the psychology of anxiety. Levitt noted that:

> The mental health professional regards anxiety as a painful, debilitating, even catastrophic condition that cries for alleviation. Anxiety as a malignancy is a limited concept. It considers the emotion only in the extreme intensity in which it disrupts behavior.

> Moderately intense anxiety, however, energizes the organism and improves performance. The distinction appears to be a sheer matter of degree. The urgent need is to acquire the knowledge to utilize anxiety constructively, to be its master and not its slave.

Similarly, McCandless and Evans (1973) note the negative aspects of extreme anxiety and suggest that moderate levels of anxiety enhance performance on a variety of psychomotor and cognitive tasks.

McCandless and Castaneda (1956) reported on the correlations between anxiety as defined by the score for the CMAS and academic achievement as measured by sub- and composite scores on the Iowa Every Pupil Test (IEPT). Fourth, fifth and sixth grade students served as subjects. The results were presented as follows (p. 379): "For groups where relationships exist, there is a tendency for the more complicated skills (reading, arithmetic, and composite performance) to suffer more interference from anxiety than simpler mnemonic skills such as spelling."

Gaudry and Spielberger (1971) and Grimes and Allinsmith (Rosenblith and Allinsmith, eds., 1962) examined the relationship between structured and unstructured teaching methods and anxiety. The results indicated that high anxious subjects performed better in the structured treatment. Dowaliby (Berliner and Cahen, 1973) hypothesized that high anxious versus low anxious college students would perform differentially under high-structured and low-structured teaching methods. The high structured treatment was defined as teacher-centered. Student-centered methods were designated as low-structure. The personality variable measure was the Taylor Manifest Anxiety Scale. The

results were similar to those obtained in the Gaudry-Spielberger and the Grimes-Allinsmith studies. A theoretical link between induction and anxiety was established by Tallmadge and Shearer (1971). The study included inductive discovery, expository deductive treatments and a composite anxiety measure. Significant interaction effects were obtained. High anxious subjects scored significantly higher than low anxious subjects in the inductive discovery treatment. In the expository deductive treatment, opposite results were obtained. Due to the fluctuation in subject matter area and grade levels, the only relatively safe inference is that the construct of anxiety interacts with instructional treatments.

Dependency. Flanders, Anderson, and Amidon developed the Dependence Proneness Scale (DPS) during the late 1950's and early 1960's. High dependent prone students were characterized as:

> ... students that respond to teacher directions with meticulous compliance; they are forever checking with the teacher to see if each step is correct; they have a strong need for support, reassurance and supervision. (Flanders, et al., 1961, p. 575)

Low dependent prone students were said to:

> ... react with the opposite symptoms. Once they start work they prefer to be left alone; they initiate few contacts with the teacher; their need for adult approval is more easily submerged in their task orientation. (p. 575)

In comparing high dependent prone students to low dependent prone students, Anderson (Flanders, Anderson, and Amidon, 1961, p. 584) found that high dependent prone students preferred a less directive teacher. When a

teacher accepts or clarifies the feelings or ideas of a student, or provides praise or encouragement, he is exhibiting indirect teacher influence. Verbal statements indicative of more directive teacher influence focus attention on a problem, and/or interject teacher authority. It appears that the more supportive atmosphere created by the less directive teacher more adequately meets the needs of the high dependent student.

Domino (1971) reported a significant interaction between the personological variables of independent achievement orientation and conforming achievement orientation and instructional treatments designated as high and low structure. One hundred students, selected on the basis of their extreme scores on the Achievement-via-Conformance and Achievement-via-Independence scales of the California Personality Inventory, were assigned to introductory psychology sections taught in either a conforming or an independent manner. The achievement criterion was the final examination. Achievement was maximized when instructional treatment and achievement orientation were consonant. The study confirmed Domino's (1968) previous findings.

Tuckman (1969) classified students as either concrete-dependent or abstract-independent. Instructional treatments were categorized along a directive-non-directive dimension. The directive teacher was defined as one who "... used a high degree of structuring in his course." (p. 637). The sample was made up of 344 eleventh and twelfth grade students at a vocational-technical high school. Final course grades were utilized as the measure of

achievement. The results indicated that "abstract independent students differentiated in favor of nondirective teaching." (p. 638).

Flanders (1965) categorized seventh and eighth grade mathematics and social studies students as high, medium, or low in terms of dependence proneness. Teachers were classified as either most direct or most indirect by the authors. Disordinal interactions were not obtained; however, inspection of Table 5.9, page 101, suggests that: (1) achievement scores of low dependent subjects were higher than those of the high dependent subjects in both mathematics and social studies with teachers classified as most indirect; and (2) the findings were reversed with teachers classified as most direct.

The findings of a study conducted by Crocker, Bartlett and Elliott (1976) were inconsistent with the findings previously discussed. The dependency variable (DPS scores) did not exhibit the postulated interaction with treatment. Teaching structure was defined by the amount of teacher control. Achievement test scores were obtained after four sixth grade classes had completed two science process-oriented units. The findings were muddled by a class-treatment interaction. As the authors stated, "The problem of determining which specific pupil characteristics are related to teaching strategies remains unresolved." (pp. 272-273).

Concept Studies

Need for Concept Studies. The importance of concepts in science is reflected in statements like, "The place of concepts in science has been

well established by scientists in their attempts to unify their observations and descriptions of nature." (Helgeson, 1967, p. 1). Concepts have been the focus of research in such diverse areas as cognitive development, methodological comparisons, instrument development and curricular content. Voelker (1973) identified and discussed 163 concept-related studies. Clark (1971, p. 253) noted that, "Over the past thirty years there have been well over 250 experimental studies conducted in the area of concept attainment."

The explosive nature of science content demands that concepts rather than isolated facts be taught. As Esler (1973, p. 21) suggests, "Instead of dealing with isolated facts, the content of science may best be studied as a number of big ideas or concepts." The need for continued investigation in concept learning is summarized by Garone (1960, p. 104): "Concept development is so intricately related to children's total development, teachers and parents need to know and understand more about it."

Characterization of Concepts. There appears to be more agreement on the need for concept studies than on what constitutes a concept. Archer (Klausmeier and Harris, 1966), Pella (1966), Kendler (Melton, 1964) and Hunt (1962) presented varied definitions of concepts.

The study of concept learning is further complicated by variability in concept types, learning difficulty, and concept complexity (i.e., number of dimensions). Pella (1966, p. 33) describes three systems of concepts: "The system of concepts that facilitates description of phenomena is largely

classificational in nature; the system of concepts that facilitates prediction is largely correlational in character; and the system of concepts that facilitates the explanation of phenomena is made up of theories of verbal, mechanical, or mathematical varieties."

Pella suggested the examination of science concepts for the purpose of determining their individual characteristics (e.g., their origin and nature). As an example of this procedure, Pella (1966, p. 32) pointed out the nature of the correlational concept--force:

> A force is a push or pull which tends to change the motion of a body. This statement
> 1. is a symbolic representation.
> 2. is a decision made by man.
> 3. is a decision based upon human experience with natural phenomena.
> 4. is an abstraction from a field of experience.
> 5. is a generalization that includes more than the field of personal experience.
> 6. involves the conscious or rational relating of facts. (The push or pull is correlated with a change in motion.)
> 7. describes a man-made idea.
> 8. describes an idea that may exist at various levels of complexity (contact and noncontact forces).
> 9. is useful in making predictions and interpretations.

Concepts have also been classified on the basis of the relationship(s) between concept instances. Hunt and Hovland (1960) discussed three types of classification of instances: conjunctive, disjunctive and relational. Concept types are distinguished as follows (p. 220):

> In the conjunctive type all of the instances have features in common, so the concept is one where each instance possesses characteristic A and B, or A and B and C, etc. In the case of disjunctive concepts, all instances have one or another feature. The third type is relational, in which the common properties are sets of relationships rather than common specific stimulus.

Bruner, Goodnow, and Austin (1956) noted that disjunctive concepts are extremely difficult to learn.

One might expect that simple concepts (i.e., concepts containing only one dimension) would be acquired before complex concepts. Smedslund (1964) found that a complex concept may be acquired prior to simple concept formation providing the complex concept fits the child's cognitive level while the simple concept does not.

Raven (1967-68) compared psychological and logical concept sequences thought to be necessary for the understanding of momentum by primary school (K-3) children. The logical sequences include conservation of matter--speed--the proportional use of mass and speed--momentum. The psychological sequence was momentum--conservation of matter--proportional use of mass and speed--speed. The results indicated that the development of the momentum concept followed the psychological sequence. Raven (p. 222) explained the finding as follows:

> Young children use broad categories when they describe natural phenomena. Their perceptions are global. Thus, the primary school child can have a concept of momentum without understanding the subcomponents. Primary school children can acquire and use higher order concepts providing the concept dimensions fit their cognitive level.

Psychological Influences (Growth and Development). The studies by Smedslund and Raven in part provide the impetus for developing a psychological perspective regarding both content and grade level selection. It is most noteworthy that Inhelder and Piaget (1958) have shown that children around the age

of ten are able to manipulate force, mass, acceleration, velocity and time variables proportionately.

Piaget (1964) elaborated a theory of cognitive development in which he identified four major stages in child development:

1. Sensory-motor, preverbal stage (0-2 years).
2. Pre-operational representation (2-7 years).
3. Concrete operations (7-11 years).
4. Formal operations (12-15 years).

According to Piagetian theory, students in the fifth and sixth grades are at the concrete operations stage. "Concrete operations are logical operations, such as classifications, seriations, symmetry, one-one or one-many correspondences, and so on; but their use is limited to actual objects or materials." (Beard, 1969, p. 27)

Piaget typically demonstrated a natural phemonenon to a child and then conducted an interview centering around the child's observations. Piaget recognized that there is not a set age at which children pass from one stage to another. Maturation, experience, social transmission or linguistic transmission and equilibration affect the age at which a child attains a certain level of cognitive development.

Numerous researchers such as Deutsche (1937), Elkind (1961) and Raven (1972) have conducted studies similar to those of Piaget. Deutsche administered two tests of causal relations to 732 third to eighth grade children. Test two consisted of twelve verbal questions. The conclusions tended to contradict Piaget's earlier postulation concerning the nature of children's

cognitive development.

Elkind (1961) replicated Piaget's work concerning the conservation of mass, weight and volume by 5-12 year old children. Elkind's study differed from Piaget's investigation in its standardization of procedures and its use of statistical design. The results agreed with Piaget's finding regarding the ages at which children discover the conservation of mass, weight and volume. In both studies, the conservation of mass did not usually appear before the ages 7-8; the conservation of weight did not usually appear before the ages 9-10; and the conservation of volume did not usually appear before the age of 11.

Raven (1972) studied the development of the concept of acceleration in children in grades three through six. Eight different concept tasks were administered to all children. The results indicated that simultaneous and successive motion activities involving the use of intensive operations could be presented to third and fourth grade children and that activities involving successive motion that use extensive logical operations could be used with some fifth and sixth grade children. Intensive operations include relating distance to speed or time to speed. Extensive operations require the comparison of concept components with one another and the repetitive use of a unit (p. 206). The findings were in close agreement with those of Piaget (1970).

Grade placement studies as reported by Helgeson (1968), Pella and Stauss (1967-68), and Pella and Carey (1967-68) provide information concerning the matching of subject matter and grade level. "The primary purpose

of such studies is to determine whether students at a particular grade level, having particular personal characteristics, can learn the concepts as measured by the investigator's assessment technique." (Voelker, 1973, p. 23).

In Helgeson's (1967, pp. 2-3) research, the major problem was:

> To determine the relative levels of understanding of selected concepts from within the conceptual scheme--force--achieved by pupils in grades two through six as indicated by scores on knowledge, comprehension and application type pencil and paper tests when all subjects receive comparable instruction.

The results of particular interest are: (1) at the knowledge and comprehension levels, grade five and six pupils met the criterion for success on all eight concepts; and (2) at the application level, grade five and six pupils met the criterion for success on six of the eight concepts.

A limited number of research studies have been reported which were designed to determine the effects of student manipulation of science objects on achievement. Such studies by Huttenlocher (1962), Butts (1963), Carlson (1967), Benson (1968), Brown (1968), Siegel (1971), and MacBeth (1974) are related in that they were concerned with elementary school students and with the importance of manipulative experience. Generally, the results of these studies indicated nonsignificant differences between manipulator and nonmanipulator treatments. Much fluctuation was noted concerning the specifications of the nonmanipulator treatments.

Inductive/Discovery Learning

Need for Research Within Inductive/Discovery Learning. The impetus for continued research in inductive/discovery learning was expressed by participants at a conference on discovery learning (reported in Shulman and Keislar, 1966); the conclusion was reached that the research evidence was "relatively impoverished" (p. 105) and that there is much room for research in discovery learning. The tendency of current research such as Babikian (1971), Tanner (1969) and Coulter (1966) is to pit one method against another. Typically, the researchers fail to adequately define the inductive/discovery variable(s). In addition, such investigations have yielded contradictory results or nonsignificant differences. In consideration of the problem, Strike (1975, p. 45) noted that, "Part of the difficulty has been that there is little agreement concerning what a discovery method is and what a discovery method is supposed to accomplish.

Babikian (1973, p. 175) suggests that "many studies which deal with discovery methods result in equivocal outcomes because they significantly differ from one another in the amount of guidance they provide." In addition, Babikian (p. 175) stated that "the discovery method is actually a generic instructional procedure which encompasses a series of methods on a continuum between minimal and maximal guidance." This definition generally applies to the variation in conditions (i.e., independent to guided discovery) which have been labeled "Discovery" in the studies reported in this chapter.

The ramifications of different inductive/discovery strategies must be understood prior to undertaking comparative methodological research.

Benefits of Inductive/Discovery Learning. Inductive/discovery methods imply active pupil participation and varying amounts of student independence or self-direction. Early scholars, Rousseau (Strike, 1975, p. 461), Montessori (1912), and Dewey (1916) have advocated active student involvement and discovery. Many of the experimental science curriculum projects of the sixties reflect their authors' concern for both induction and active pupil involvement. Suchman (1960), Bruner (1961, 1960), Hawkins (Shulman and Keislar, 1966) and Butts (1963) provide theoretical support for independent learning, active pupil involvement and inductive/discovery methods.

According to Suchman (1960), autonomous discovery experiences provide the learner with a plan of operation that will help him discover causal factors of physical change through his own initiative. The student learns to formulate hypotheses, test them and interpret the results. Suchman (Butts, 1963, pp. 135-136) described the importance of independent learning as follows: "... independence is a key factor because the abundant opportunity to obtain new concepts through inquiry or autonomous discovery forces the student's perceptions to be evaluated and reorganized in line with experience."

Bruner (1961) hypothesized four benefits of discovery learning: increased intellectual potency, intrinsic motivation, the learning of the heuristics of discovery, and enhanced use of memory. Bruner noted (p. 31) that, "Once the heuristics of discovery have been mastered, they constitute a state of problem-solving or inquiry that serves for any kind of task one may encounter." The importance of active student involvement is reflected in statements like " ... the schoolboy learning physics is a physicist and it is easier for him to learn physics behaving like a physicist than doing something else." (Bruner, 1960, p. 21). The value of inductive-discovery strategies was emphasized by Hawkins (Shulman and Keislar, 1966, p. xi) who "takes the position that there are certain kinds of things that can be learned only by discovery." Butts (1963) suggested that independent experience with science phenomena is a necessary and sufficient condition for concept development. Even Ausubel (1963), who has been a critic of discovery learning, suggests that such methods may be applicable for students at the concrete stage of cognitive development. Hence, there is a great deal of theoretical support for, and interest in, this instructional strategy, the essence of which lies in inductive generalization.

Levels of Learning (Knowledge and Process). Henkel (1967) investigated the effects of discovery-oriented laboratory, traditional curriculum utilizing laboratory experiments, and a discussion method upon the critical thinking ability of college physics students. Zingaro and Collette (1967-68) compared an inductive laboratory method with a traditional laboratory

method in terms of gains in critical thinking ability among college physical science students. In both studies, critical thinking ability was significantly enhanced by participation in the inductive/discovery treatments.

Friot (1970) found that students, grades seven through nine, exposed to an inductive-discovery science course showed significantly greater gains in terms of logical thinking ability than students taking a traditional lecture-demonstration course. Pre- and post-tests using Piagetian tasks were utilized to ascertain changes in reasoning ability.

McConnell (1934), Ray (1961), and Haslerud and Meyers (1958) involved second grade, ninth grade and college level subjects, respectively, in studies to compare the transferability of inductively derived principles and skills with those acquired by directed-deductive methods. Haslerud and Meyers (p. 296) found that " ... independently derived principles are more transferable than those where the principle is given to the student." McConnell's study yielded similar results. Ray found significant differences in favor of the discovery treatment. Guthrie (1967, p. 45) also noted that " ... discovery methods facilitate transfer ...".

Boeck (Schefler, 1965) compared inductive and deductive methods of high school chemistry laboratory instruction in terms of knowledge of the scientific method and ability to perform in the laboratory. Similarly, Rainey (1965) utilized laboratory performance as a criterion of achievement in high school chemistry. Treatments consisting of highly directed and nondirected

laboratory exercises were developed by Rainey. Significant results were obtained in both studies in favor of the more discovery-oriented treatment. Thomas and Snider (1969) studied the effects of guided discovery and didactic methods on instruction upon the acquisition of certain inquiry skills. The results indicated that the guided discovery method was superior for the acquisition of inquiry skills.

Scott (1966) included three hundred fourth, fifth and sixth grade students in a study to determine the influence of a "Yes-No" type of inquiry upon the subjects' styles of categorization. The control group was taught by conventional methods. Learning materials included fifteen science concepts, five at each grade level. Six styles of categorization had been previously identified by the researcher. It was assumed that the styles were intimately tied to the child's conceptual behavior. Scott concluded (p. 153) that: "(1) the inquiry strategy encourages an analytical mode on the part of a child that leads him beyond the overt perceptual phenomena inherent in our physical world; and (2) inquiry subjects were more flexible in their classification behavior than those children taught conventionally."

Independent Discovery. Studies such as those conducted by Kline (1971), Kersh (1958), Kittell (1957), and Craig (1956) suggest that content information can be acquired through independent discovery. The studies differed in content, grade level and experimental design. Each study included a treatment designated as self-directed, no teacher direction or simply

independent discovery. Although no significant differences were obtained by the four researchers, it was typically concluded that "some" teacher direction was needed. The question remains--How much teacher control is most appropriate? It should also be noted that subjects in all minimal structure treatments acquired content information in amounts not significantly different from students in the more structured treatments.

Summary

The literature review was conducted to gain some background and insight to six questions related to this research. The questions and the resulting decisions are discussed below.

1. What type of research design should be used? The literature indicates that the likelihood of obtaining disordinal interactions could be enhanced by using an ATI design which includes: (1) factorially simple student personological variables; (2) two personological variables where one is judged to correlate substantially with success in one treatment and the other is judged to correlate with success in a second treatment; and (3) a moderately low or nonsignificant correlation between the two selected personological variables. In addition, this portion of the review of the literature suggests that personality traits are factorially simple. The following decisions were made: (1) two student personological variables were selected, and (2) the correlation between the two personological variables would be determined as part of a pilot study. However, six treatment conditions were included in the

design instead of two as suggested in the literature. These conditions corresponded to the standard components of traditional laboratory exercises. The relative success of students in varied treatment conditions and classified on the basis of two personological characteristics is discussed under question two.

2. What personological variables should be selected? The research provides some support for hypothesizing that in an inductive learning environment where high anxiety seems to be an advantage, this advantage may be greater if the tasks are highly structured. The literature suggests that while the high dependent student may prefer a less directive teacher, achievement may be facilitated by more directive teaching. It seems that low dependent student achievement may be enhanced with less directive teaching methods. The student personological variables of anxiety and dependency were included as blocking variables.

3. What concepts should be selected? The literature suggests that concepts within the conceptual scheme--force--as well as other correlational concepts may: (1) facilitate the acquisition of certain science process skills (e.g., prediction and interpretation); (2) be acquired by fifth and sixth grade students. In a study which includes science knowledge and processes acquisition as dependent variables, the utilization of correlational concepts within the conceptual scheme--force--seems appropriate.

4. What physiological/psychological variables need to be controlled? The evidence suggests that age and level of cognitive development affects a child's ability to: (1) manipulate force, mass, acceleration, velocity, and

time variables proportionately; (2) conserve mass, weight and volume; and (3) acquire force-related concepts. A measure of the student's ability to perform concrete operations was used to control for level of cognitive development. Age was controlled by limiting the sample to students in grades five and six.

5. What teaching method should be used? The literature suggests that inductive/discovery methods may increase critical and logical thinking ability, transfer of learning, encourage an analytical mode of thought, and facilitate the acquisition of certain science process skills. The use of actual objects and materials was supported to facilitate logical operations by students at the concrete operations stage. Hence, a method within the domain of inductive/discovery methods was developed and included in this study. This method incorporated student hands-on experience with science equipment within a laboratory setting, and ranged from a highly teacher controlled to a highly student controlled inductive/discovery learning experience.

6. What criterion measures should be used? Clearly, the research indicated that inductive/discovery methods can result in enhanced "higher level" mental processes: critical thinking ability, reasoning ability, and transfer of learning. Even more intimately related to science process (observation, comparison, etc.) achievement are laboratory performance, inquiry skills, and analytical modes of thought. To account for the influence of structure in inductive/discovery methods, both knowledge and process measures were used.

CHAPTER III

METHODS AND PROCEDURES

The chapter consists of a discussion of: (1) the development of the instructional tasks, science content and treatments; (2) variables and instruments used; (3) pilot study (major questions and resulting study modifications); (4) site selection and sampling; and (5) data gathering and analysis techniques. Instructional tasks, instruments developed by this researcher, instrument reliability information generated from the pilot study and science resources used in task development are included in the appendices.

Instructional Task Development

The task development procedure was divided into four phases. The initial phase was as follows: (1) identification of an idea; (2) review of three to five texts or laboratory manuals at different grade levels that pertain to the concept in question; (3) check of difficulty level against existing upper-elementary science activities; (4) determination of whether or not the concept could be modified to fit the instructional task format; (5) test of the activity in the laboratory; (6) writing of the task in draft form; and (7) comparison of the new with previously developed tasks in terms of difficulty and format. At this point, pretreatment information was drafted in script form. This information was

designed to standardize student knowledge of equipment, relevant terms, calculations and measurements prior to treatment. Ten tasks each with pretreatment information resulted from this phase.

Phase II was a review by five Ohio State University professors. The faculty members were requested to consider the following points: (1) the relative difficulty of each task; (2) the equivalence of task components among instructional tasks; (3) the organization or relationship between the tasks; (4) the academic accuracy of each task; and (5) the readability of task components. Conferences with each professor followed the review. The reviewers expressed concern about the difficulty of the tasks and the accuracy of one task (subsequently deleted). They found the task components to be equivalent among the instructional tasks and the tasks to be horizontally organized (Task 1 is not a prerequisite for Task 2, etc.). Since the tasks were found to be horizontally organized, the sequence of tasks could be randomly determined. As a result of Phase II: (1) one task was deleted; (2) an appropriate sequencing procedure was ascertained; (3) plans for a pre-pilot trial of the tasks with elementary school students were initiated; and (4) the tasks were revised.

A pre-pilot trial of the tasks with a small group of elementary students was conducted to determine student reaction(s) to the activities, task difficulty and readability. Reading level and difficulty appeared consonant with student ability; however, some revision was warranted. Each student acquired a verbal understanding of the concepts. A fourth grade reading level was obtained using the Fry Readability Formula (1968).

Time constraints imposed by public school officials limited the number of tasks to five. To help decide which tasks to eliminate, the participating teachers were asked to comment on the appropriateness of the tasks. Based on the information gained during the aforementioned phases, five tasks and pre-treatment information were developed and implemented in the pilot study. The consistency of the students' data reported on worksheets was of paramount importance in the final task revisions. Few inconsistencies were identified; hence, with minor revisions, the tasks were deemed suitable for implementation in this study.

Science Content

Five correlational concepts from within the conceptual scheme--force--constitute the science content of the instructional tasks. Each concept is composed of two components; one is manipulated in a manner which exemplifies a specific relationship (i.e., a positive instance). The knowledge level posttests were limited to the measurement of the subjects' understanding of these relationships. An indicator or measure of the effects of each concept component manipulation contributes to the definition of the correlational concept. Examples of measurements and calculations, equipment descriptions, definitions of relevant terms, and graphing instructions were presented from a script (pretreatment information) prior to treatment. Measurement examples were presented so that they did not constitute a concept instance. Pretreatment information served to reduce subject differences attributable to varied

content backgrounds and grade levels.

The five concepts are listed, relevant equipment is described and the relationship between each pair of concept components is discussed in the remaining paragraphs of this section. The concept number corresponds to the instructional task number.

Concept 1: Height affects impact force. Equipment included a box of sand with a meter stick attached, a sinker, and a depth of depression measurer (a tongue depressor calibrated in millimeters). Three heights were labeled on the meter stick. The height from which the sinker was dropped into the sand was manipulated. The greatness of the resulting depression(s) as indicated by the depth of depression measures illustrated the effect of varying heights on impact force. The relationship to be discovered was--as the height from which the sinker was dropped increased, the impact force increased.

Concept 2: Weight affects speed. Equipment included a ramp, a ramp stand, a cart attached through a pulley to a constant force source, three equal weights and a meter stick. Points (A, B, C) were labeled on the ramp. The force source was used to pull the cart up the ramp from Point B to the pulley (Point C). The amount of weight placed on the cart was manipulated. The number of seconds required for the cart to move from Point B to Point C indicated the effect of varying amounts of weight on the cart's speed. The relationship to be discovered was--as the amount of weight placed on the cart increased, the speed of the cart decreased.

Concept 3: Mass affects motion. Equipment included two boxes of equal size and mass attached to each other by a rubber band, two equal masses (balls of clay) and a ruler. The boxes were labeled I and II. Point markers (A and B) were attached to tables at a predetermined distance apart. The boxes were arranged so that the distance from the front edge of Box I to Point A was equal to the distance from the front edge of Box II to Point B. When the boxes were correctly arranged, the rubber band (pulling force) was taut, but not stretched. The amount of mass placed in Box I was manipulated. The rubber band was stretched so that the front edge of Box I was parallel with Point A and the front edge of Box II was parallel with Point B. The number of inches that Box I moved from Point A illustrated the effect of varying amounts of mass on the motion of the box. The relationship to be discovered was--as the amount of mass placed in Box I increased, the motion of Box I decreased.

Concept 4: Mass affects momentum. Equipment included a ramp, ramp stand, a cart, three objects of equal mass, a wooden block, and a meter stick. The wooden block was placed at the end of the ramp opposite the end elevelated by the ramp stand. The cart rolled down the ramp and struck the wooden block. The amount of mass placed on the cart was manipulated. The distance that the block was knocked by the cart exemplified the effect of varying amounts of mass on the cart's momentum. The relationship to be discovered was--as the amount of mass placed on the cart increased, the momentum of the cart increased.

Concept 5: Weight affects the force of friction. Equipment included a wooden block attached to a force-measurer (a spring scale calibrated in newtons) by a string and three objects of equal weight. The block was pulled a predetermined distance (Point A to Point B). The amount of weight placed on the wooden block was manipulated. The force-measurer reading(s) (number of newtons) indicated the effect of varying amounts of weight on the force of friction. The relationship to be discovered was--as the amount of weight placed on the wooden block increased, the force of friction increased.

Treatments

Five fifty minute periods (one per day) made up the instructional sequence. Each instructional period contained three segments: (1) pretreatment information--ten minutes; (2) treatment--thirty minutes; and (3) knowledge level posttest--ten minutes. Treatments were administered by the investigator.

Teaching structure refers to the relative amounts of teacher and/or student control within each of the five instructional tasks. Worksheets were used to regulate the amount of teaching structure. Subjects assigned to the most structured treatment (i.e., Group A) received worksheets which included six task components. To reduce teaching structure, one task component was deleted per treatment group. Hence, subjects assigned to Group F received only one task component. See Table 1.

TABLE 1

SIX LEVELS OF TEACHING STRUCTURE

	Decreasing Teaching Structure					
	Group A	Group B	Group C	Group D	Group E	Group F
1. Area of Investigation	*TC	TC	TC	TC	TC	TC
2. Arrangement of Equipment	TC	TC	TC	TC	TC	SC
3. Specific Variables to Investigate	TC	TC	TC	TC	SC	SC
4. Number and Type of Measurements	TC	TC	TC	SC	SC	SC
5. Data Analysis Procedures	TC	TC	SC	SC	SC	SC
6. Written Questions	TC	**SC	SC	SC	SC	SC

*TC -- Teacher Controlled
**SC -- Student Controlled

Students assigned to less structured groups were: (1) required to rely more heavily on their own cognitive capacities and perceptions to discover the concepts; and (2) given more responsibility for procedural decisions. To maximize the effect of the treatments, subjects were not permitted to ask questions of the teacher or talk to other students during the treatments. Students were encouraged to seek clarification during the pretreatment information segment of the instructional periods. In addition, a seating arrangement was established (e.g., subjects assigned to Groups A and F were separated as far as possible) and cardboard partitions were used to prevent nonverbal communication.

All subjects received Task Component 1, "Area of Investigation." This component tended to limit the number of experimentation options and provided minimal direction. The "Arrangement of Equipment" refers to the

physical location of the apparatus at each laboratory station. When this component was teacher controlled (Groups A-E), a suggested investigative procedure was given. Task Component 3 identified and described task variables and served to focus student attention on specific variables in the investigations. Task Component 4 delineated specific measurement instructions and resulting data recording methods. Task Component 5 refers to directions concerning all calculations and/or graphing instructions. Task Component 6 included written questions and answers. Group A (the most structured group) received worksheets which included components one through six.

The students were instructed to experiment with the equipment upon completion of reading and following worksheet directions. The most structured group had little time (zero to three minutes) for student controlled experimentation. Hence, subjects in the less teacher controlled groups were required to make more procedural decisions and rely more heavily on their own cognitive capacities.

Variables and Instruments

Subjects' manifest anxiety and dependence proneness scores were gathered by using the Children's Manifest Anxiety Scale (CMAS) and a modified version of the Dependence Proneness Scale (DPS). The CMAS was developed by Castaneda, McCandless, and Palermo (1956, pp. 318-319). The DPS was developed by Flanders, Anderson, and Amidon (1961, pp. 580-582). Subjects scoring at or above the sample median on the CMAS and DPS were classified as

High Anxiety (HA) and High Dependent (HD). Others were classified as Low Anxiety (LA) and Low Dependent (LD), respectively. The subjects were placed in one of the four possible personality groups, HAHA, HALD, LAHD, or LALA, and randomly assigned to one of the six treatments.

The criteria for low (knowledge) level concept understanding included: (1) five posttest scores, collected after each instructional period; and (2) the composite of five knowledge level posttests. The criteria for high (science processes) level concept understanding included: (1) the total score on the Test of Science Inquiry Skills (Riley, 1972); and (2) four science process subscores (i.e., inferring, predicting, interpreting data and identifying and controlling variables).

The Test of Science Inquiry Skills (TSIS) and the Concept Component Pretest (CCP) were used with twenty-eight randomly selected subjects (i.e., seven from each personality group) to assess differences in science knowledge and processes prior to treatment among the four personality groups. The pretested students did not receive treatment.

The Ankney-Joyce Reasoning Test (1974) was utilized as a covariate in a computation involving the science knowledge and processes criteria. Instrument item analysis, reliability and validity are presented in the remaining paragraphs of the section. Pilot study item analyses are presented in Appendix D.

Personality Test 1: Children's Manifest Anxiety Scale. This instrument was developed to extend the generality of the Taylor scale of

manifest anxiety to populations ranging in age from six to twelve. The CMAS includes 53 items in which the child indicates agreement (Yes) or disagreement (NO) regarding the applicability of the behavior to himself. Forty-two items refer to manifest anxiety (A) and 11 items relate to an L Scale that provides an index of the subject's tendency to falsify responses. The anxiety score was obtained by summing the number of anxiety items answered "Yes."

One week retest reliabilities with 386 fourth, fifth and sixth grade students were reported at .90 for the anxiety scale and .70 for the L Scale (Castaneda et al., 1956). The author noted the desirability of low intercorrelations between the A and L Scales. The findings of several studies in which the CMAS was used have been in the expected directions, suggesting construct validity. McCandless and Castaneda (1956) found that children with high CMAS scores make significantly more errors than non-anxious subjects in a complex learning task. Palermo (1959) found that A Scale mean scores for Negro children (grades four to six) were significantly higher than those for white children. Concurrent validity is supported by a correlation coefficient of .78 between CMAS and Sarason's Score for Anxiety obtained by Grams (Johnson and Bommarito, 1971).

The A Scale item analysis obtained in this study showed a KR20 value of .86, mean item difficulty of .56, and mean item discrimination of .43 with a population of 245. The L Scale item analysis showed a KR20 value of .69, mean item difficulty of .82, and mean item discrimination of .39 with a population of 245. The intercorrelation between the A and L Scales was found to be -.08.

Personality Test 2: Dependence Proneness Scale. The DPS includes 45 items in which students are requested to indicate agreement or disagreement regarding the applicability of the behavior to themselves. It was designed to measure dependence proneness of children grades three through six and eight. The items are keyed for dependence proneness for answers that either agree (A) or disagree (D) with the item statement. The dependence proneness score was obtained by summing the number of responses keyed for dependence proneness. A Hoyt reliability coefficient of .68 was obtained by Flanders (1961). The validity of the instrument may be assessed from the following: (1) The final scale was developed on the basis of several item analyses (i.e., only items from an original pool of 150 items which discriminated well between extreme groups were retained). (2) Amidon (Flanders et al., 1961) found that a high dependent score is associated with failure to take an extreme position on an opinionnaire and that high and low dependent students exhibited predicted differences on separate measures of dependence in the classroom. (3) Flanders (1965) found that high scoring subjects indicated more desire for support and approval during learning sessions compared with low scoring subjects.

Testing time constraints and the reading difficulty with several items evidenced by pilot study subjects required a reduction in the number of items. The modified version contained thirty items. The obtained Hoyt reliability coefficient showed a value of .67 with a population of 245. Inspection of the pilot study high-low dependency group using both the 45 and 30 item scales indicates a 98 percent agreement between the scales.

Measures of Low Level Concept Understanding. One knowledge level (Bloom, 1956) posttest was developed for each of the five instructional tasks. The tests were designed to measure student knowledge of the relationship defined by correlational concept components. Each test contains ten multiple choice items. The tests were administered during the last ten minutes of each instructional period. The composite of all five tests (50 items) is the sixth measure of the subjects' low level concept understanding. Item analysis results are presented in Table 2.

TABLE 2

SUMMARY OF ITEM ANALYSES FOR MEASURES OF LOW LEVEL CONCEPT[a] UNDERSTANDING

Knowledge Posttests	Mean Item Difficulty	Mean Item Discrimination	KR20
Task 1	.13	.36	.76
Task 2	.42	.62	.72
Task 3	.46	.70	.80
Task 4	.27	.71	.86
Task 5	.21	.57	.79
Composite[b]	.30	.46	.91

N=168

[a]Concept Task 1: Height affects impact force
Concept Task 2: Weight affects speed
Concept Task 3: Mass affects motion
Concept Task 4: Mass affects momentum
Concept Task 5: Weight affects the force of friction

[b]Composite score of the five knowledge posttests

The test development procedure supports the content validity of the knowledge level measures. The method described by Stanley and Hopkins (1972, pp. 102-105) was followed with each of the five tests. In addition: (1) a test specification grid was constructed and used in item development; (2) relevant terms were defined prior to treatment which served to reduce incidental prerequisites; and (3) the content population was restricted to one specific relationship and further limited by "knowledge level" delimitation. The posttests are presented in Appendix B.

Measures of High Level Concept Understanding. The Test of Science Inquiry Skills (TSIS) was developed by Riley (1972) to measure the process skills of inferring, predicting, interpreting data and identifying and controlling variables. Each process skill and the total score of four process skills are considered criteria of high level concept understanding. This 50 item, multiple choice test was designed for fifth grade students. Typically, the items present a situation by a drawing or diagram. Questions are then asked that can be answered based on the given information. Riley reported a KR20 value of .90. Validation (pp. 76 and 109) was provided by a panel of science educators and correlation with the Science Test (Form A) of the Sequential Test of Educational Progress (Series III).

Item analyses computed in this study are presented in Table 3.

TABLE 3

SUMMARY OF ITEM ANALYSES FOR MEASURES OF HIGH LEVEL CONCEPT UNDERSTANDING

Process[a]	Number of Items	Mean Item Difficulty	Mean Item Discrimination	KR20
A	12	.36	.66	.77
B	11	.42	.44	.55
C	18	.38	.48	.73
D	9	.43	.60	.60
E	50	.39	.46	.89

N=168

[a]Process A: Inferring
Process B: Predicting
Process C: Interpreting data
Process D: Identifying and controlling variables
Process E: Composite of four subscores

Concept Component Pretest. This test consists of eleven phrases (List A) and eleven concept components plus one distractor (List B). The phrases evolved from examination of six fifth grade science textbooks. The test was designed to identify science knowledge differences among the four personality groups. The knowledge level pretest scores were obtained by summing the number of correct phrase-concept component matches.

The instrument was modified (i.e., readability of two phrases) after utilization in the pilot study. Item weighting was employed to maximize the reliability of each item and internal consistency of the instrument. Computations were completed using the FORTAP (RAVE) PROGRAM as described by Bauman (1973). A correct response to all items would be a score of 21.

The face validity of this instrument is supported by the fact that the data being sought were relatively fixed and finite (i.e., items were limited to the knowledge of concept components as they were used in this study). The output showed a Hoyt reliability value of .77, a mean of 7.21, and a standard deviation of 5.43 with a population of twenty-eight.

Covariate: Ankney-Joyce Reasoning Test. This paper-and-pencil test was developed by Ankney and Joyce (1974) to evaluate the concrete reasoning ability of children, aged eight to fourteen. Ten Piagetian concepts or cognitive structures (e.g., conservation of weight, volume, area, length) were investigated on this test. Three items were developed for each cognitive structure or concept cluster. Subjects were classified as concrete operational on each concept if they were successful on at least two of the three items. Further, students were assigned an overall rating of concrete if they achieved 80 percent of the concept clusters (p. 97).

Ankney and Joyce obtained a KR20 value of .83 with a population of 129. A significant relationship ($p \leq 0.01$) between the paper-and-pencil test and a hands-on concrete operations version (p. 86) supports the test's concurrent validity. A significant ($p \leq 0.01$) point biserial correlation between two test forms supports predictive validity (p. 103).

The item analysis obtained in this study showed a KR20 value of .76, mean item difficulty of .41, and a mean item discrimination of .39, with a population of 245.

Pilot Study

The influence of the pilot study on the development of the instructional tasks, science content and knowledge level pre- and posttests has been discussed in the preceding sections. The data gathering and analysis procedures were consonant with those discussed later in this chaper. The item analyses results of all tests are presented in Appendix D. Therefore, this section is restricted to a brief discussion of the sample and four major concerns. Since the resolution of these concerns tends to explain and support the sampling, data gathering and analysis techniques employed in this study, they are discussed at this point.

A sample of 112 fifth and sixth grade students from an elementary school in the Mansfield, Ohio, area was chosen to participate in the pilot study. Seventy-two subjects received treatment, 11 subjects received additional pretesting, and the remaining 29 subjects' participation terminated after the initial testing (personality and concrete operations).

Concern 1: Sampling. Concern 1 was to determine the feasiblity of restricting the sample to those subjects obtaining extreme scores on the personality measures and operating at the concrete level. It was determined that such restriction would severely reduce cell size. Since differences in cognitive development existed, it was deemed a necessary covariate.

Concern 2: Relationship between personological variables. The correlation between the scores on the anxiety and dependency measures was of interest because: (1) a significant (positive) correlation could mean that only one construct was being measured, and (2) a high negative correlation would have prevented the formation of four personality groups due to the small overlap between the two distribution curves. The resulting correlation coefficient was -.26. Hence, four personality groups could be formed and it seems fairly safe to assume that two distinct constructs were being measured.

Concern 3: Treatment groups and amount of manipulation. Since subjects assigned to the more structured treatment groups were required to do more reading, writing, and calculating, it was suspected that subjects assigned to the less structured groups may have spent more time handling the equipment. Amount of manipulation was the percent of six minutes that the subjects handled the equipment. Subjects were randomly selected and timed with a stopwatch. The resulting data were analyzed using ANOVA. See Table 4.

TABLE 4

ANALYSIS OF VARIANCE OF EQUIPMENT MANIPULATION SCORES BY INSTRUCTIONAL TREATMENT

Source	df	MS	F	F (critical)
Between Groups	5	17.20	.093	2.77
Within Groups	18	185.55		
Total	23			

$p \leq .05$

No significant ($p \leq 0.05$) main effects were obtained among treatment groups in regard to amount of manipulation. Significant differences would have warranted treatment modifications.

Concern 4: Differences among the four personality groups prior to treatment. Twenty-one students were randomly selected from the four personality groups and given the Concept Component Pretest and the Erie Science Process Test (Mayer, 1974). The subjects did not receive treatment. ANOVA was performed with each criterion. See Table 5.

TABLE 5

ANALYSIS OF VARIANCE OF KNOWLEDGE OF CONCEPT COMPONENTS BY PERSONALITY GROUPS

Source	df	MS	F	F (Critical)
Dependency (A)	1	.75	.17	5.32
Anxiety (B)	1	2.08	.47	
A x B (AB)	1	14.08	3.18	
Error (S/AB)	8	4.42		
Total	11			

$p < .05$

No significant ($p \leq 0.05$) interaction or main effects were obtained with the knowledge level measure. Hence, concern for the confounding effects of pretreatment science knowledge differences was reduced.

A second ANOVA was performed with the science processes data. See Table 6.

TABLE 6

ANALYSIS OF VARIANCE OF SCIENCE PROCESSES UNDERSTANDING BY PERSONALITY GROUPS

Source	df	MS	F	F (Critical)
Dependency (A)	1	4.08	.35	5.32
Anxiety (B)	1	2.08	.18	
A X B (AB)	1	24.08	2.08	
Error (S/AB)	8			
Total	11			

$p < .05$

No significant ($p \leq .05$) interaction or main effects were obtained with the science processes level measure. Since no significant differences were found, concern for the confounding effects of pretreatment science processes understanding was lessened.

The Erie Science Process Test (ESPT) was replaced with the Test of Science Inquiry Skills due to a relatively low ESPT test-retest reliability (.64).

Site Selection and Sampling (Main Study)

This study involved two elementary schools from one Columbus area school district. This district was considered suburban based on its geographic location. It was assumed a relatively small suburban district would have less social, economic and cultural diversity than a larger urban district. There is but one fifth and one sixth grade class at School II. Many of the students at School II are sent to School I after completing the fourth grade. For this

reason, differences between subjects from School I and II seem relatively small. Students from four fifth grade classes (three from School I, one from School II) and six sixth grade classes (five from School I, one from School II) agreed to participate in the study. Consent letters were sent to all parents and the study was discussed with teachers and students prior to testing. All parents, teachers and students agreed to participate.

Initially, 245 students (198 from School I and 47 from School II) were tested. Twenty-eight students were randomly selected for additional testing, and 168 were randomly assigned to the treatment groups on the basis of the two student personality characteristics. The distribution of the students to one of the twenty-four groups is shown in Table 7 and a data analysis diagram is presented in Table 8.

TABLE 7

DISTRIBUTION OF THE SUBJECTS
OF THE STUDY

Personality	Treatment						
	A	B	C	D	E	F	N
High Anxiety-High Dependent	7	7	7	7	7	7	42
High Anxiety-Low Dependent	7	7	7	7	7	7	42
Low Anxiety-High Dependent	7	7	7	7	7	7	42
Low Anxiety-Low Dependent	7	7	7	7	7	7	42
Total Number	28	28	28	28	28	28	168

TABLE 8

DATA ANALYSIS DIAGRAM[a]

Personality		Treatment					
		A	B	C	D	E	F
High Anxiety	High Dependency						
	Low Dependency						
Low Anxiety	High Dependency						
	Low Dependency						

[a]Data were analyzed in a 2 x 2 x 6 design with seven subjects assigned to each of the twenty-four cells.

Data Gathering and Analysis

The Children's Manifest Anxiety Scale, the Modified Dependence Proneness Scale, and the Ankney-Joyce Reasoning Test were administered to 245 students on the first day of data collection. Identification numbers were assigned to subjects and utilized in all data analyses. Scores were obtained from item analyses (STATPACK ITEMA) printouts. The Hoyt reliability coefficient was obtained for the Modified Dependence Proneness Scale using the FORTAP (RAVE) PROGRAM. Reasoning test scores were used as a covariate with all criteria in subsequent analyses. A score at or above the sample median was used to place a student in the high half of the Anxiety continuum. The same procedure was used with Dependence Proneness scores. The students were identified as either High Anxiety-High Dependent (HAHD), High Anxiety-Low Dependent (HALD), Low Anxiety-High Dependent (LAHD), or Low Anxiety-Low Dependent (LALD). Seven subjects from each

personality group were randomly selected to receive the science knowledge and processes pretests. The FORTAP (RAVE) PROGRAM was used to compute an item analysis on the Concept Component Pretest. The STATPACK ITEMA Program was used to compute item analyses on the Test of Science Inquiry Skills, total and each of the four subscales. The science knowledge and processes pretest data were analyzed using the Multivariate Analysis of Variance (MANOVA) by Clyde (1969) in a 2 x 2 multivariate analysis of covariance design with one covariate and six dependent variables.

Of the remaining students, 168 were randomly selected to receive treatment. These students were randomly assigned by personality groups to the six treatment groups (A-F). This resulted in a 2 x 2 x 6 analysis of variance design with seven subjects per cell.

After treatment group membership was established, scheduling conferences were held with the ten cooperating teachers. It was determined that the instructional sequence (five tasks--one/day) would be presented in three sessions. Each session included the instructional sequence and the administration of the science knowledge and processes measures.

Session I included sixty-three subjects from four classes (three sixth grade and one fifth grade) at School I. Six instruction groups were formed from existing classes. In most cases an instruction group consisted of twelve subjects from two or three existing classes. The tasks were presented in five fifty minute instructional periods (one/day). Knowledge level posttests were administered following each instructional period. On the day following the

the completion of the instructional sequence, the Test of Science Inquiry Skills was administered to the 63 subjects in a large group setting. Item analyses were run using the STATPACK ITEMA Program on the five knowledge level posttests, the composite of the five knowledge level posttests, the four science process subscores and the total science process test. Student responses on the aforementioned tests were coded and punched on IBM cards.

Session II included 69 subjects from four classes (two sixth grade and two fifth grade) at School I. Six instruction groups were formed from existing classes. Instruction group size, class composition (i.e., students from two or three existing classes), mode of task presentation, the instructional sequence, testing, and item analyses were identical to that employed during Session I.

Session III included 36 subjects (one sixth grade and one fifth grade) at School II. Three instruction groups (twelve subjects/class) were formed from existing classes. Each instruction group consisted of fifth and sixth grade students. The mode of task presentation, the instructional sequence, testing and item analyses were identical to those employed during Sessions I and II.

The knowledge level posttest data were analyzed in a 2 x 2 x 6 multivariate analysis of covariance with six dependent variables (i.e., five knowledge level posttests and their composite) and one covariate (Ankney-Joyce Reasoning Test) using the MANOVA Computer Program by Clyde (1969). The science processes level data were analyzed in a 2 x 2 x 6 multivariate analysis

of covariance with five dependent variables (i.e., four science process subscores and their total) and one covariate (Ankney-Joyce Reasoning Test) using the MANOVA Computer Program by Clyde (1969). When interactions were investigated, Dunn's (Kennedy, 1974) method of multiple comparisons was employed on the adjusted cell means.

To provide a source of explanatory information, the Statistical Package for the Social Sciences, PEARSON CORR, (Nie et al., 1975) was used to compute correlation matrices including: (1) Anxiety A and L Scales; (2) Dependence Proneness and Anxiety (A Scale); and (3) the eleven dependent variables and the covariate.

CHAPTER IV

RESULTS OF THE STUDY

The results of this study will be presented in three sections: (1) support for covariate use; (2) descriptive data for the Anxiety and Dependency measures; and (3) MANCOVA results. First, the correlations of the eleven dependent variables and the covariate will be discussed in support of using the Ankney-Joyce Reasoning Test scores as a covariate. Additional support is provided by comparing differences in science knowledge and processes understanding among the four personality groups without and with the covariate included in the analyses. To acquire these data, seven subjects were randomly selected from each of the four personality groups and the Test of Science Inquiry Skills and the Concept Component Pretest were administered. These twenty-eight students did not receive treatment. The results of the science knowledge and processes pretests analyses are presented in Section One. Tables of raw and adjusted cell means and standard deviations by cell are available in Appendix F. Raw and adjusted cell means associated with significant interaction or main effects appear in the text.

Descriptive data for the Anxiety and Dependency measures are presented in Section Two. Descriptive data were generated from: (1) item analyses (mean, median, standard deviation, kurtosis, and skewness of the overall

sample distribution); and (2) 2 x 2 x 6 (Anxiety, Dependency, Teaching Structure) analyses of the Anxiety scores and the Dependency scores. The ANOVA results provide standard deviations by cell strata and cell means. The above information as well as the interaction effects and main effects will aid in the interpretation of the effects of Anxiety and Dependency used as blocking variables in the main study.

The third section will present the results of the MANCOVA. This section is organized by study hypotheses. The sequence of presentation is: (1) second-order interactions; (2) first-order interactions; and (3) main effects. Significant interactions and main effects are summarized at the conclusion of this section.

When interactions were investigated, Dunn's Procedure (1961) was performed on the adjusted cell means. Kennedy (1974, p. 5.60) provides the following general formula:

$$\hat{\Psi} = \underline{t}_{\alpha/c}\sqrt{\frac{2 \cdot \underline{MS}_{S/A}}{\underline{n}}}$$

where $\hat{\Psi}$ = the least significant difference convention; $\underline{t}_{\alpha/c}$ = a critical $\underline{t}$ value at an alpha level (α) with a specific number of pairwise comparisons ($\underline{c}$); $\underline{MS}_{S/A}$ = mean square for error; and $\underline{n}$ = number of subjects per cell. When significant interactions and/or main effects are discussed, adjusted cell means are presented. Other adjusted cell means, raw cell means and standard deviations by cell are available in Appendix F.

Support for Covariate Use

Dependent Variables and Covariate Intercorrelations. Correlations were calculated by using the Statistical Packages for the Social Sciences (PEARSON CORR) with the covariate and the eleven criteria used in this study. The correlations were calculated from these data provided by the 168 subjects who received treatment.

The correlations are presented in support of: (1) utilizing the reasoning test scores as a covariate and (2) the use of multivariate statistics. All correlations were significant ($p \leq 0.001$); see Table 9.

TABLE 9

CORRELATIONS[a] WITH THE COVARIATE[b] AND THE DEPENDENT VARIABLES[c]

Covariate and Criteria	A	B	C	D	E	F	G	H	I	J	K	L
A	-	47	43	50	38	39	52	54	56	45	61	59
B	47	-	45	44	45	55	50	48	56	40	56	73
C	43	45	-	49	45	40	51	43	47	41	54	76
D	50	44	49	-	41	37	53	44	53	45	58	75
E	38	45	45	41	-	48	40	46	47	38	50	77
F	39	55	40	37	48	-	48	42	53	44	55	73
G	52	50	51	53	39	48	-	63	69	68	89	65
H	54	48	43	44	46	42	63	-	61	66	82	60
I	56	56	47	53	47	53	69	61	-	60	88	68
J	45	40	41	45	38	44	69	66	60	-	83	56
K	61	58	54	58	50	55	89	82	88	83	-	73
L	58	73	76	75	77	73	65	60	68	56	73	-

[a]Correlations have been rounded to two places and decimals omitted.

[b]Ankney-Joyce Reasoning Test scores, the covariate, abbreviated A

[c]Dependent variable list: B, Knowledge Posttest Task 1; C, Knowledge Posttest Task 2; D, Knowledge Posttest Task 3; E, Knowledge Posttest Task 4; F, Knowledge Posttest Task 5; G, inferring; H, predicting; I, interpreting data; J, identifying and controlling variables; K, total process test; L, total knowledge postte

Pretest Analyses. Additional testing was implemented to determine whether differences in knowledge of concept components and selected science processes existed among the four personality groups (i.e., High Anxiety-High Dependency, High Anxiety-Low Dependency, Low Anxiety-High Dependency, and Low Anxiety-Low Dependency) and if these differences could be reduced by

including a covariate in the analyses. Such differences could confound the interpretation of treatment effects.

Prior to randomly assigning students to treatment groups based on the two student personality characteristics, twenty-eight students (seven from each of the four personality groups) were randomly selected to participate in a sixty minute pretesting session. The Test of Science Inquiry Skills and the Concept Component Pretest were administered during this period. Students from School I and School II were included and tested on the same day. The individuals were told that they would receive awards for participation and high achievement. However, the students were not told that they would not be included in the activities.

Pretest data analyses included: (1) a 2 x 2 multivariate analysis of variance (MANOVA) and a 2 x 2 multivariate analysis of covariance (MANCOVA) where the four science process subscores (inferring, predicting, interpreting data, and identifying and controlling variables) and knowledge pretest scores were the dependent variables; and (2) a 2 x 2 ANOVA and a 2 x 2 ANCOVA with the total scores on the science processes measure as the dependent variable. The Ankney-Joyce Reasoning Test (AJRT) scores were the covariate in each ANCOVA. ANOVA results are presented first followed by ANCOVA findings for the first-order interactions and main effects. The effects of the covariate on pretreatment differences among personality groups are summarized at the conclusion of this subsection.

Test of Anxiety-Dependency interactions--ANOVA. First-order interaction results were generated from two analyses, one which included the total science process scores as the criterion and the second which included scores on four science process subscales and knowledge pretest scores as the criteria. Results of both analyses are summarized in Table 10.

TABLE 10

MANOVA FOR ANXIETY BY DEPENDENCY INTERACTIONS WITH FIVE DEPENDENT VARIABLES: FOUR SCIENCE PROCESS SUBSCORES AND KNOWLEDGE PRETEST SCORES, AND FOR ANXIETY BY DEPENDENCY WITH TOTAL SCIENCE PROCESS SCORES[a]

Multivariate Tests of Significance Using Wilks Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.54	5.00	20.00	.218

Univariate F Tests

Variable	F(1,24)	Mean Square	P Less Than
Inferring	.88	85.75	.356
Predicting	.43	43.75	.516
Inter-Data	.37	38.89	.548
Id. Con. Var.	4.40	408.89	.047
Know Pretest	1.54	46.29	.227
Process Total	1.29	128.57	.268

[a]Total science process scores were not analyzed with the four process subscores and knowledge pretest scores; hence, the scores did not contribute to the multivariate F test.

The multivariate F was not significant ($p \leq 0.10$); hence caution should be exercised when considering the univariate F tests. Two-way interaction effects resulted for one variable, identifying and controlling variables ($p \leq 0.047$). Cell means are presented in Table 11.

TABLE 11

RAW CELL MEANS OF IDENTIFYING AND CONTROLLING VARIABLES PRETEST FOR ANXIETY BY DEPENDENCY INTERACTION

Anxiety	Dependency		H-L
	High	Low	Diff.
High	56.71	44.86	11.35
Low	47.43	50.86	-3.43
H-L Diff.	9.28	-6.00	

number of subjects per cell = 7
Dunn's t (critical value) = 12.51 : $p \leq 0.10$

Using Dunn's procedure, post-hoc comparisons yielded no significant differences ($p \leq 0.10$). A discussion of Dunn's procedure was presented earlier in this chapter.

Tests of Anxiety-Dependency interactions--ANCOVA. The Ankney-Joyce Reasoning Test scores were employed as a covariate in two analyses, one which included the total science process scores as the criterion and the second which included scores on four science process subscales and knowledge pretest scores as the criteria. Results of both analyses are presented in

Table 12.

TABLE 12

MANCOVA FOR ANXIETY BY DEPENDENCY INTERACTIONS WITH FIVE DEPENDENT VARIABLES: FOUR SCIENCE PROCESS SUBSCORES AND KNOWLEDGE PRETEST SCORES AND FOR ANXIETY BY DEPENDENCY WITH TOTAL SCIENCE PROCESS SCORES[a]

Multivariate Tests of Significance Using Wilks Lambda Criterion

Test of F Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.41	5.00	19.00	.267

Univariate F Tests

Variable	F (1,23)	Mean Square	P Less Than
Inferring	.62	57.69	.439
Predicting	.15	9.87	.705
Inter.Data	.17	15.83	.684
Id. Con. Var.	4.03	309.16	.057
Know Pretest	1.16	31.82	.292
Process Total	.91	73.09	.351

[a]Total science process scores were not analyzed with the four process subscores and knowledge pretest scores; hence, the scores did not contribute to the multivariate F test.

The multivariate F was not significant ($p \leq 0.10$); hence, caution should be used in interpreting the results of the univariate F tests. First-order interaction effects resulted for one variable, identifying and controlling variables ($p \leq 0.057$). Adjusted cell means are presented in Table 13.

TABLE 13

ADJUSTED CELL MEANS OF IDENTIFYING AND CONTROLLING VARIABLES FOR ANXIETY BY DEPENDENCY INTERACTION

Anxiety	Dependency		H-L
	High	Low	Diff.
High	55.29	47.59	7.70
Low	45.64	51.33	-5.69
H-L Diff.	9.65	-3.74	

number of subjects per cell = 7
Dunn's t (critical value) = 11.41 : $p \leq 0.10$

Post-hoc analysis yielded no significant differences ($p \leq 0.10$) among personality groups for identifying and controlling variables. The differences between the High Anxiety-High Dependency and High Anxiety-Low Dependency means (Table 11) were reduced (i.e., relative to their critical values) when the covariate was included in the analysis (Table 13).

Tests of Anxiety and Dependency Main Effects--ANOVA. The main effects results were obtained from the two aforementioned analyses. The results are summarized in Table 14.

TABLE 14

SUMMARY OF MANOVA FOR ANXIETY AND DEPENDENCY MAIN EFFECTS WITH FIVE DEPENDENT VARIABLES: FOUR SCIENCE PROCESS SUB-SCORES AND KNOWLEDGE PRETEST SCORES, AND FOR ANXIETY AND DEPENDENCY WITH TOTAL SCIENCE PROCESS SCORES[a]

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Tests of Anxiety Main Effects				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.47	5.00	20.00	.792
Univariate F Tests				
Variable	F (1,24)		Mean Square	P Less Than
Inferring	.23		22.32	.636
Predicting	.66		66.04	.426
Inter. Data	.01		.89	.927
Id. Con. Var.	.20		18.89	.656
Know Pretest	.01		.14	.946
Process Total	.07		7.00	.794
Tests of Dependency Main Effects				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.71	5.00	20.00	.621
Univariate F Tests				
Variable	F (1,24)		Mean Square	P Less Than
Inferring	3.91		378.89	.060
Predicting	2.44		246.04	.131
Inter. Data	2.13		222.90	.157
Id. Con. Var.	1.34		124.32	.259
Know Pretest	.93		28.00	.344
Process Total	3.02		302.29	.095

[a]Total science process scores were not analyzed with the four process subscores and knowledge pretest scores; hence, the scores did not contribute to the multivariate F tests.

The multivariate F tests for the anxiety and dependency main effects were not significant ($p \leq 0.10$). The results of the univariate tests of anxiety main effects were nonsignificant. Significant main effects resulted for inferring ($p \leq 0.060$) and process total ($p \leq 0.095$), between levels of dependency, Table 15.

TABLE 15

SUMMARY OF MANOVA DEPENDENCY MAIN EFFECTS: RAW CELL MEANS FOR INFERRING AND SCIENCE PROCESS TOTAL

Criteria	Dependency		H-L
	High	Low	Diff.
Inferring	53.86	46.50	* 7.36
Process Total	53.50	46.93	** 6.57

* $p \leq 0.060$
** $p \leq 0.095$
number of subjects per level = 14

The high dependent subject was more successful than the low dependent subject on the inferring and the process total measures.

Tests of Anxiety and Dependency Main Effects--ANCOVA. The main effects results were obtained with the Anxiety by Dependency interaction results presented earlier in this subsection. Results are presented in Table 16.

TABLE 16

SUMMARY OF MANCOVA FOR ANXIETY AND DEPENDENCY MAIN EFFECTS WITH FIVE DEPENDENT VARIABLES: FOUR SCIENCE PROCESS SUB-SCORES, KNOWLEDGE PRETEST SCORES, AND FOR ANXIETY AND DEPENDENCY WITH TOTAL SCIENCE PROCESS SCORES[a]

Multivariate Tests of Significance Using Wilks Lambda Criterion

Tests of Anxiety Main Effects				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.43	5.00	19.00	.823
Univariate F Tests				
Variable	F (1,23)		Mean Square	P Less Than
Inferring	.07		6.12	.800
Predicting	.17		11.14	.688
Inter. Data	.17		15.70	.685
Id. Con. Var.	.78		59.45	.388
Know Pretest	.13		3.61	.720
Process Total	.02		1.20	.904
Tests of Dependency Main Effects				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.50	5.00	19.00	.775
Univariate F Tests				
Variable	F (1,23)		Mean Square	P Less Than
Inferring	1.83		170.06	.189
Predicting	.21		14.11	.651
Inter. Data	.51		47.37	.483
Id. Con. Var.	.08		6.08	.781
Know Pretest	.07		1.94	.792
Process Total	.72		57.71	.406

[a]Total science process scores were not analyzed with the four process subscales and the knowledge pretest; hence, the scores did not contribute to the multivariate F tests.

No significant ($p \leq 0.10$) anxiety or dependency main effects resulted from these analyses. To facilitate the ANOVA-ANCOVA comparison, the adjusted cell means for inferring and process total for levels of dependency are presented in Table 17.

TABLE 17

SUMMARY OF MANCOVA DEPENDENCY MAIN EFFECTS: ADJUSTED CELL MEANS FOR INFERRING AND SCIENCE PROCESS TOTAL

Criteria	Dependency		H-L
	High	Low	Diff.
Inferring	52.83	47.53	5.30
Process Total	51.76	48.67	3.09

number of subjects per level = 14

With the inclusion of AJRT scores as a covariate, differences between high and low dependent subjects are reduced for the inferring and process total measures.

Summary. To justify the use of AJRT scores as a covariate in main study analyses, the dependent variables and covariate intercorrelations were computed, and pretest data were analyzed in ANOVA and ANCOVA designs. Significant correlations ($p \leq 0.001$) between the covariate and dependent variables and among the dependent variables support the use of AJRT scores as a covariate.

ANOVA and ANCOVA two-way interaction effects were reported first, followed by anxiety and dependency main effects. Two-way interaction effects ($p \leq 0.047$) resulted for identifying and controlling variables in the ANOVA. In the ANCOVA, two-way interaction effects ($p \leq 0.057$) resulted for identifying and controlling variables. Post hoc analysis (Dunn's Procedure) yielded nonsignificant ($p \leq 0.10$) differences.

Little difference was noted between the ANOVA and ANCOVA results for anxiety main effects. It appears that pretreatment differences in science processes and knowledge levels of understanding between subjects assigned to levels of anxiety were relatively small.

Significant dependency main effects in the ANOVA resulted for two variables: (1) inferring ($p \leq 0.060$); and (2) process total ($p \leq 0.095$). In comparison, the results of the ANCOVA yielded nonsignificant differences: (1) inferring ($p \leq 0.189$); and (2) process total ($p \leq 0.406$). These findings strongly support the use of AJRT scores as a covariate.

Descriptive Data--Anxiety and Dependency Measures

Subjects were classified as high or low for anxiety and dependent proneness relative to the distribution of the sample. Hence, descriptive data are needed to interpret these independent variables.

Anxiety Data. A score of 18 (sample median) was used to place a student in the high half of the High-Low Anxiety continuum. The Anxiety Scale item analysis obtained in this study showed an overall mean of 18.61,

standard deviation of 7.20, skewness of 0.28, kurtosis of -0.57 and a range of 35 (maximum score 36 and minimum score 1). Group statistics are presented in Table 18.

TABLE 18

GROUP STATISTICS--ANXIETY SCALE

	PerCent Students	Number Students	Mean Scale	Standard Score (M = 50, SD = 10)
Total	100.00	245	18.61	50.00
Upper	25.71	63	28.30	63.46
Lower	28.16	69	10.23	38.36

A 2 x 2 x 6 ANOVA was performed with standardized anxiety scores (mean of 50 and a standard deviation of 10) as the dependent variable. Anxiety, Dependency, and Treatments were the independent variables. Table 19 presents the results of this analysis.

TABLE 19

ANALYSIS OF VARIANCE OF ANXIETY SCORES BY ANXIETY, DEPENDENCY AND TREATMENTS

Source	df	MS	F	P Less Than
Anxiety (A)	1	12154.99	424.13	.001
Dependency (D)	1	470.00	16.40	.001
Structure (S)	5	33.04	1.15	.335
A x D (AD)	1	4.34	0.15	.698
A x S (AS)	5	36.76	1.28	.275
D x S (DS)	5	29.71	1.04	.399
A x D x S (ADS)	5	57.44	2.00	.081
Error (S/ADS)	144	28.66		
Total	167			

Cell means, Anxiety by Dependency level means and standard deviations are presented in Table 20.

TABLE 20

MEANS AND STANDARD DEVIATIONS OF ANXIETY SCORES BY ANXIETY, DEPENDENCY AND TREATMENTS AND ANXIETY BY DEPENDENCY LEVEL MEANS[a]

Personality		Treatment							
		A	B	C	D	E	F	Level	
	High	55.43	54.43	55.14	57.29	59.29	60.29	56.98	M
High	Dependency	5.65	4.69	4.18	8.10	6.05	7.85		SD
Anxiety	Low	56.43	63.86	58.43	61.14	56.29	63.86	60.00	M
	Dependency	4.54	8.78	6.15	4.78	6.97	5.15		SD
	High	38.57	39.86	41.29	40.57	38.43	39.14	39.64	M
Low	Dependency	4.20	5.82	4.75	4.93	5.26	3.58		SD
Anxiety	Low	45.00	44.29	41.29	40.71	44.71	43.86	43.31	M
	Dependency	3.16	3.68	3.35	5.62	2.43	2.12		SD

[a]Level means are the Within Anxiety By Dependency Contrast
$n = 7$
$\bar{X} = 50.00$

Significant main effects ($p \leq 0.001$) resulted between levels of Anxiety and levels of Dependency. See Table 21.

TABLE 21

MEANS OF ANXIETY SCORES FOR ANXIETY AND DEPENDENCY MAIN EFFECTS

Contrast	Independent Variables	
	Anxiety	Dependency
High	58.49	48.31
Low	41.48	51.66
H-L Diff.	17.01*	-3.35*

* $p \leq 0.001$
number of subjects per level = 84

High Anxiety students scored significantly higher ($p \leq 0.001$) on the anxiety measure than Low Anxiety students. Low Dependency students scored significantly higher ($p \leq 0.001$) than High Dependency students on the anxiety measure.

Descriptive data not directly associated with significant interaction or main effects are presented in Table 22.

TABLE 22

SUMMARY OF MEANS OF ANXIETY SCORES: WITHIN STRUCTURE, ANXIETY BY STRUCTURE, AND DEPENDENCY BY STRUCTURE CONTRASTS

Treatment	Contrasts				
	Structure	Anxiety		Dependency	
		High	Low	High	Low
A	48.86	55.93	41.79	47.00	50.71
B	50.61	59.14	42.07	47.14	54.07
C	49.04	56.79	41.29	48.21	49.86
D	49.93	59.21	40.64	48.93	50.93
E	49.68	57.79	41.57	48.86	50.50
F	51.79	62.07	41.50	49.71	53.86

Within Structure - number of subjects = 28
Within Anxiety By Structure - number of subjects = 14
Within Dependency By Structure - number of subjects = 14

Dependency Data. A score of 76 (sample median) was used to place a student in the high half of the High-Low Dependency continuum. The Dependency Scale item analysis for this study showed an overall mean of 73.43, standard deviation of 19.79, skewness of -0.17, kurtosis of -0.11, and a range of 113 (maximum score 126 and minimum score 13). Group statistics are presented in Table 23.

TABLE 23

GROUP STATISTICS - DEPENDENCY SCALE

	Per Cent Students	Number Students	Mean Score	Standard Score (m = 50, SD = 10)
Total	100.00	245	73.43	50.00
Upper	28.16	69	96.49	61.65
Lower	27.76	68	48.44	37.37

A 2 x 2 x 6 ANOVA was performed with standardized dependency scores (mean of 50, and a standard deviation of 10) as the dependent variable. Anxiety, Dependency, and Treatments were the independent variables. See Table 24.

TABLE 24

ANALYSIS OF VARIANCE OF DEPENDENCY SCORES BY ANXIETY, DEPENDENCY, AND TREATMENTS

Source	df	MS	F	P Less Than
Anxiety (A)	1	184.38	5.65	.019
Dependency (D)	1	9782.87	299.93	.001
Structure (S)	5	5.31	0.16	.976
A x D (AD)	1	11.52	0.35	.553
A x S (AS)	5	46.24	1.42	.221
D x S (DS)	5	82.19	2.52	.032
A x D x S (ADS)	5	39.41	1.21	.308
Error (S/ADS)	144	32.62		
Total	167			

Cell level means and standard deviations are presented in Table 25.

TABLE 25

MEANS AND STANDARD DEVIATIONS OF DEPENDENCY SCORES BY ANXIETY, DEPENDENCY AND TREATMENTS AND ANXIETY BY DEPENDENCY LEVEL MEANS[a]

Personality		Treatment							
		A	B	C	D	E	F	Level	
	High	54.29	56.00	55.43	53.71	57.29	60.86	56.26	M
High	Dependency	2.69	4.28	2.99	4.07	4.86	5.98		SD
Anxiety	Low	44.43	41.29	44.71	39.57	42.86	36.29	41.52	M
	Dependency	5.41	5.65	4.82	3.95	8.34	8.36		SD
	High	60.57	57.29	56.57	61.14	57.28	60.43	58.88	M
Low	Dependency	7.83	3.68	5.83	6.28	6.26	5.97		SD
Anxiety	Low	43.43	45.86	41.14	44.43	42.71	41.00	43.10	M
	Dependency	3.55	4.38	7.08	5.53	6.34	7.55		SD

[a]Level means are the Within Anxiety by Dependency Contrast
$n = 7$
$\bar{X} = 50.00$

Dependency by Treatments (Structure) interaction effects resulted for the dependency scores ($p \leq 0.032$). Level means are presented in Table 26.

TABLE 26

MEANS OF DEPENDENCY SCORES BY DEPENDENCY AND TREATMENTS

Treatment	Dependency		H-L
	High	Low	Diff.
A	57.43	43.93	13.50
B	56.64	43.57	13.07
C	56.00	42.93	13.07
D	57.43	42.00	15.43
E	57.29	42.79	14.50
F	60.64	38.64	22.00

number of subjects per level = 14

Table 26 suggests that the Dependency by Treatment interaction is ordinal (i.e., High Dependency students scored higher than Low Dependency students at all levels of structure), thus warranting the consideration of main effects. However, the relatively large mean differences between levels of Dependency at Treatment F could provide implications for the interpretation of main study MANCOVA results.

Anxiety and Dependency main effects are presented in Table 27.

TABLE 27

MEANS OF DEPENDENCY SCORES FOR ANXIETY AND DEPENDENCY MAIN EFFECTS

Contrast	Independent Variables	
	Anxiety	Dependency
High	48.89	57.57
Low	50.99	42.31
H-L Diff.	-2.10*	15.26**

* $p \leq 0.019$
** $p \leq 0.001$
number of subjects per level = 84

Low Anxiety subjects scored significantly higher ($p \leq 0.019$) on the dependency measure than the High Anxiety subjects. High Dependency subjects scored significantly higher ($p \leq 0.001$) than Low Dependency subjects on the dependency measure.

Descriptive data not directly associated with significant interaction or main effects are presented in Table 28.

TABLE 28

SUMMARY OF MEANS OF DEPENDENCY SCORES: WITHIN STRUCTURE AND ANXIETY BY STRUCTURE CONTRASTS

Treatments	Contrasts		
	Structure	Anxiety	
		High	Low
A	50.68	49.36	52.00
B	50.12	48.64	51.57
C	49.46	50.07	48.86
D	49.71	46.64	52.79
E	50.04	50.07	50.00
F	49.64	48.57	50.71

Within Structure - number of subjects = 28
Within Anxiety by Structure - number of subjects = 14

MANCOVA Results

The main study data were analyzed in a 2 x 2 x 6 design using the Multivariate Analysis of Variance Program by Clyde (1969) with one covariate (The Ankney-Joyce Reasoning Test) and eleven dependent variables. Independent variables included two levels of Anxiety, two levels of Dependency, and six levels of Teaching Structure. Knowledge level dependent variables included one ten question posttest for each of five concepts: (1) Height Affects Impact Force; (2) Weight Affects Speed; (3) Mass Affects Motion; (4) Mass Affects Momentum; and (5) Weight Affects the Force of Friction. The composite of the five knowledge level posttests was considered a dependent variable. Science Process level dependent variables included: (1) total scores for the Test of

Science Inquiry Skills; and (2) four subscores (inferring, predicting, interpreting data and identifying and controlling variables). A mean of 50 and a standard deviation of 10 were used to standardize aforementioned test scores.

This section is organized by study null hypotheses. The order of hypotheses presentation is second order interactions, first order interactions and main effects.

A brief discussion and summary of significant results is presented following the tests of main effects. A more detailed explanation of results is available in Chapter V.

The main study data satisfied the test for equality of regression; see Tables 29, 30, and 31.

TABLE 29

TEST OF EQUALITY OF REGRESSION IN ALL CELLS: VARIABLES WERE SCIENCE PROCESS AND KNOWLEDGE TOTAL SCORES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	.92	46.00	238.00	.615

Univariate F Tests			
Variable	F (23, 120)	Mean Square	P Less Than
Process Total	1.19	68.62	.266
Knowledge Total	.10	61.45	.476

TABLE 30

TEST OF EQUALITY OF REGRESSION IN ALL CELLS: VARIABLES WERE THE FIVE KNOWLEDGE LEVEL POSTTESTS

Multivariate Tests of Significance Using Wilks Lambda Criterion

Test of Roots	F	DPHYP	DFERR	P Less Than
1 through 5	.83	115.00	574.09	.896

Univariate F Tests

Variable	F (23, 120)	Mean Square	P Less Than
Know Task 1	.80	60.72	.730
Know Task 2	.72	59.23	.815
Know Task 3	1.48	93.39	.091
Know Task 4	.70	65.36	.833
Know Task 5	.80	69.60	.726

TABLE 31

TEST OF EQUALITY OF REGRESSION IN ALL CELLS: VARIABLES WERE THE FOUR SCIENCE PROCESS SUBSCORES

Multivariate Tests of Significance Using Wilks Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	1.04	92.00	465.60	.397

Univariate F Tests

Variable	F (23, 120)	Mean Square	P Less Than
Inferring	1.38	90.69	.134
Predicting	.94	66.82	.542
Inter Data	.86	59.32	.649
Id. Con. Var.	1.36	97.77	.147

Hypotheses I and II: Three-way Interactions. The hypothesis that there are no significant three-way interactions in the knowledge level variables between levels of Teaching Structure, levels of Anxiety, and levels of Dependency was not rejected ($p \leq 0.10$).

The hypothesis that there are no significant three-way interactions in the science processes level variables between levels of Teaching Structure, levels of Anxiety and levels of Dependency was not rejected ($p \leq 0.10$).

MANCOVA tables, adjusted and raw means and standard deviations for the tests of Hypotheses I and II are available in Appendix F.

Hypotheses III and IV: Two-way Interactions. The hypothesis that there are no significant two-way interactions in the knowledge level variables between levels of Teaching Structure, levels of Anxiety or levels of Dependency was rejected. A multivariate two-way interaction ($p \leq 0.10$) resulted between levels of Teaching Structure and Anxiety with the five knowledge posttests. Univariate two-way interactions ($p \leq 0.10$) occurred between levels of: (1) Teaching Structure and Anxiety (presented with the multivariate interaction) with posttest Task 1 (Height Affects Impact Force); (2) Teaching Structure and Dependency with the composite of knowledge level posttest scores; and (3) Anxiety and Dependency with the composite of the knowledge level posttest scores and the Task 2 and 3 knowledge level posttests.

The hypothesis that there are no significant two-way interactions in the science processes level variables between levels of Teaching Structure, levels of Anxiety or levels of Dependency was rejected. Two-way interactions

($p \leq 0.10$) occurred between levels of: (1) Teaching Structure and Dependency with the scores from the total science process measure and with the science process skill of identifying and controlling variables subscores and (2) Anxiety and Dependency with the scores on the total science processes measure and with subscores on the science process skills of inferring and identifying and controlling variables measures.

First order multivariate interaction--Treatment by Anxiety. When the five knowledge level posttests were considered in combination, the multivariate interaction was found to be significant ($p \leq 0.054$); see Table 32.

TABLE 32

TEST OF TREATMENT BY ANXIETY INTERACTIONS WITH FIVE KNOWLEDGE POSTTESTS SCORES

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.51	25.00	517.86	.054

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Know Task 1	1.98	145.86	.085
Know Task 2	1.40	109.73	.228
Know Task 3	1.72	116.85	.134
Know Task 4	1.63	144.19	.155
Know Task 5	.79	66.83	.556

Adjusted cell means for each of the five knowledge posttests are presented in Table 33.

TABLE 33

TREATMENT BY ANXIETY (HA-LA)[a] ADJUSTED CELL MEANS FOR THE FIVE KNOWLEDGE POSTTESTS[b]

Treatment	Tasks-Criteria									
	1		2		3		4		5	
	HA	LA	HA	LA	HA	LA	HA	LA	HA	LA
A	50.66	47.33	53.39	48.24	55.20	48.45	52.26	47.73	49.69	48.24
B	53.92	49.75	54.65	48.46	53.55	55.64	48.43	53.94	54.78	51.94
C	52.25	50.13	49.38	48.19	48.37	51.36	51.29	51.04	51.36	51.83
D	48.04	53.14	48.26	50.73	48.20	45.83	51.15	49.15	47.44	51.93
E	45.45	52.14	48.11	49.24	47.55	51.82	46.56	51.90	46.70	49.41
F	47.62	49.44	49.70	52.94	46.76	47.78	50.03	45.52	49.88	46.74

[a]HA = High Anxiety; LA = Low Anxiety
[b]Posttest 1: Height affects impact force
Posttest 2: Weight affects speed
Posttest 3: Mass affects motion
Posttest 4: Mass affects momentum
Posttest 5: Weight affects the force of friction
number of subjects per cell = 14

Inspection of Table 33 indicates that performance on Tasks 1 and 2 followed the same general pattern; that is, high anxiety students performed better as compared to low anxiety students in the more structured treatments and the reverse seems to have resulted in the less structured treatments. Student performance at levels of Anxiety on Tasks 3, 4 and 5 provided no consistent patterns across levels of Teaching Structure; see Figures 2 and 3.

Standardized discriminant function coefficients are presented in Table 34.

TABLE 34

ANXIETY BY TREATMENT STANDARDIZED DISCRIMINANT FUNCTION COEFFICIENTS FOR THE FIVE KNOWLEDGE POSTTESTS

Variable	Standardized Discriminant Function Coefficients
Task 1	0.509
Task 2	0.702
Task 3	-0.431
Task 4	-0.847
Task 5	0.227

Table 34 suggests that differences between levels of Anxiety across levels of Teaching Structure for Tasks 1 through 4 were the major contributors to the significant Anxiety by Treatment interaction. Standardized discriminant function means (Task 1 to 4 in combination) were calculated to determine at which level(s) of Teaching Structure the discrimination between high and low Anxiety was the greatest; see Table 35 and Figure 1.

TABLE 35

ANXIETY BY TREATMENT STANDARDIZED DISCRIMINANT FUNCTION MEANS WITH TASKS ONE THROUGH FOUR CONSIDERED IN COMBINATION

Treatment	Anxiety		
	High	Low	Diff. H-L
A	-4.79	-3.35	-1.44
B	1.71	-10.32	12.03
C	-3.03	-6.01	2.98
D	-5.77	1.28	-7.05
E	-3.02	-5.19	2.17
F	-3.40	3.18	-6.58

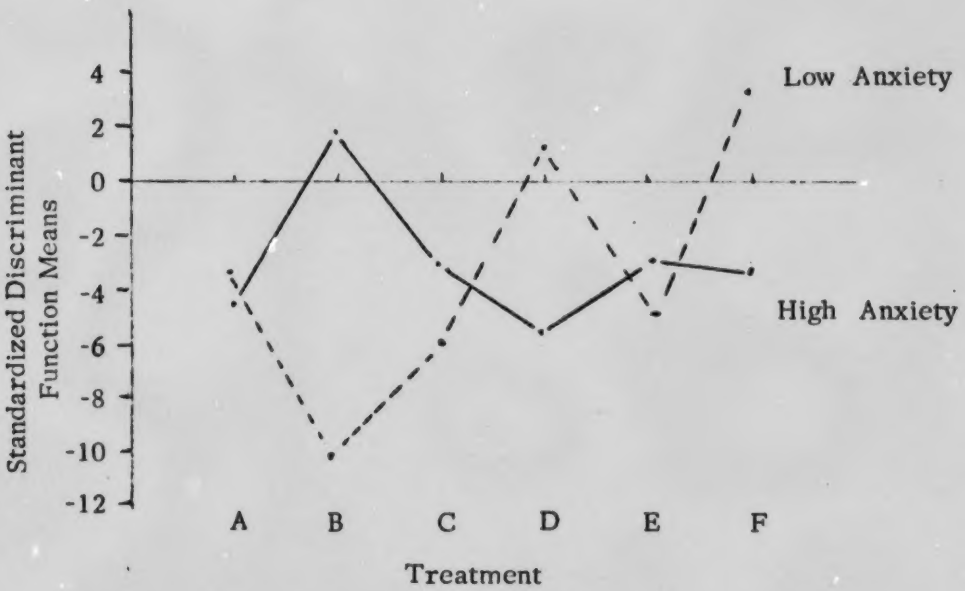


Figure 1. Discrimination between Levels of Anxiety at Levels of Teaching Structure for Knowledge Posttests One through Four in Combination

Table 35 and Figure 1 indicate that discrimination between levels of Anxiety was more pronounced at Treatments B and D. To facilitate the interpretation of performance differences, adjusted means for each of the five knowledge level posttests are plotted for both High and Low Anxiety students; see Figures 2 and 3.

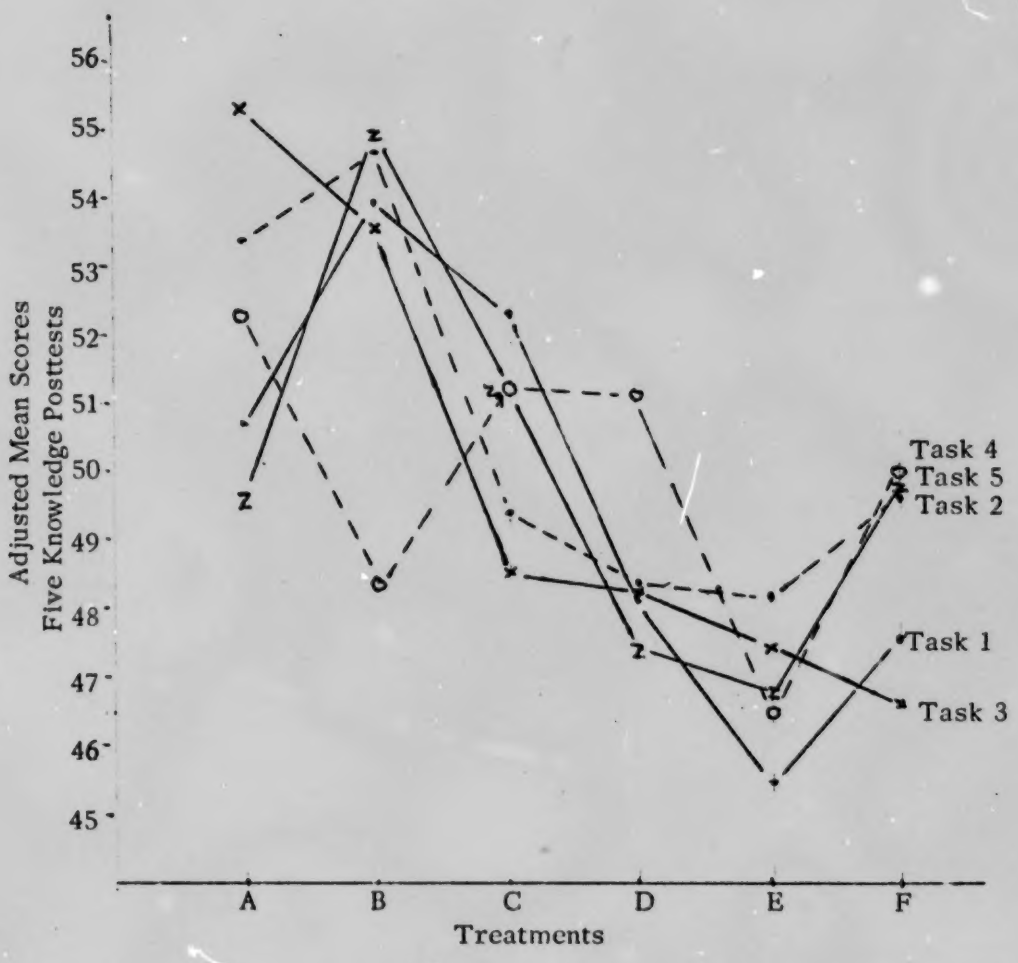


Figure 2. High Anxiety by Treatment Means for the Five Knowledge Posttests.

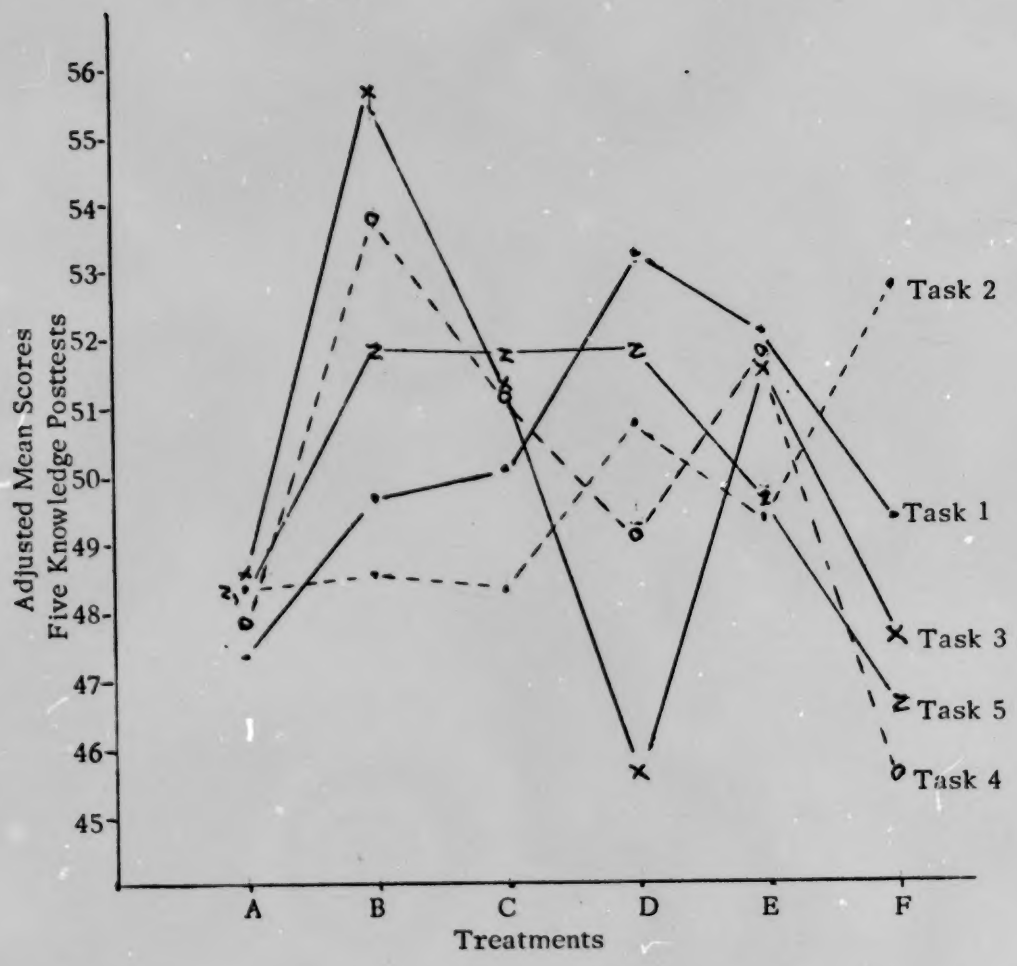


Figure 3. Low Anxiety by Treatment Means for the Five Knowledge Posttests.

High Anxiety student performance tends to lessen from Treatment B to E with Tasks 1, 2, 3 and 5. The slope of the Task 4 plot is inconsistent with other task plots from Treatment A to E.

Low Anxiety student performance tends to improve from Treatment A to E with Tasks 1 and 2. Task 3, 4 and 5 plots are inconsistent with those of Task 1 and 2.

Differences between high and low Anxiety student performance were significant ($p \leq 0.085$) for Task 1 (Table 32). The general pattern of points for Tasks 1 and 2 are similar. Post-hoc analysis of the Task 1 Treatment by Anxiety interaction yielded no significant differences ($p \leq 0.10$). The Dunn's critical value was 7.74. Task 1 adjusted means are available in Table 33.

A brief explanation of the aforementioned results is provided in the summary at the end of this chapter. A more detailed discussion is available in Chapter V.

First order interaction--Treatment by Dependency. The test of Treatment by Dependency interactions which include the knowledge total scores presented in Table 36.

TABLE 36

TEST OF TREATMENT BY DEPENDENCY INTERACTIONS WITH THE TOTAL KNOWLEDGE AND PROCESS[a] SCORES

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	1.62	10.00	284.00	.101

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Knowledge Total	1.95	119.93	.090
Process Total	2.05	121.89	.075

[a]Two-way interaction results with the process total scores will be stated later in this section.

Two-way interaction effects ($p \leq 0.090$) resulted for the composite of the five knowledge level posttests (knowledge total). Adjusted means are presented in Table 37.

TABLE 37

TREATMENT BY DEPENDENCY ADJUSTED CELL MEANS FOR KNOWLEDGE TOTAL

Treatment	Dependency		
	High	Low	Diff. H-L
A	49.91	50.79	-0.88
B	53.75	53.08	0.67
C	51.29	50.44	0.85
D	47.29	50.57	-3.28
E	44.96	52.33	*-7.37
F	50.67	45.85	4.82

*$p \leq 0.10$
number of subjects per cell = 14
Dunn's t (critical value) = 7.07 : $p \leq 0.10$

The significant interaction occurred with Treatment E, where it was found that the low dependent subjects were more successful and/or high dependent subjects were less successful in acquiring knowledge level understanding of the five concepts; see Figure 4.

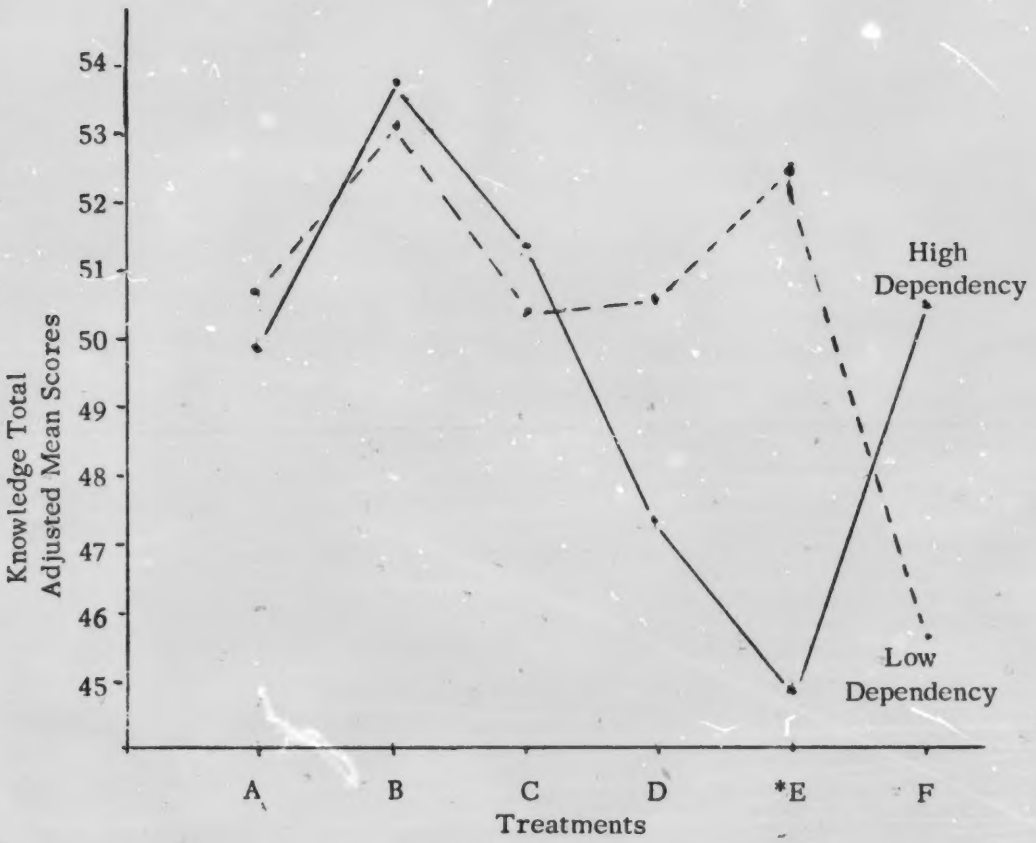


Figure 4. Interactive Effect of Treatments and Dependency on Knowledge Total.

*significant $p \leq 0.10$

There appears to be little difference between student performance at levels of dependency in the more structured treatments. Minimal structure (Treatment F) seems to have a negative effect on low dependency students.

First order interaction--Anxiety by Dependency. The test of Anxiety by Dependency Interactions for the knowledge level criteria are presented in Tables 38 and 39.

TABLE 38

TEST OF ANXIETY BY DEPENDENCY INTERACTIONS WITH TOTAL KNOWLEDGE AND PROCESS[a] SCORES

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	2.62	2.00	142.00	.084

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Knowledge Total	2.94	181.42	.088
Process Total	4.66	276.65	.033

[a]Two-way interaction results with the process total scores will be stated later in this section.

TABLE 39

TEST OF ANXIETY BY DEPENDENCY INTERACTIONS WITH THE FIVE KNOWLEDGE LEVEL POSTTEST SCORES

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	2.05	5.00	139.00	.075

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Know Task 1	2.37	174.72	.126
Know Task 2	4.53	354.94	.035
Know Task 3	3.35	227.74	.069
Know Task 4	.15	12.82	.704
Know Task 5	1.58	133.22	.211

Two-way interactions resulted for the composite of knowledge level posttest scores ($p \leq 0.088$), knowledge posttest Task 2 ($p \leq 0.035$), and knowledge posttest Task 3 ($p \leq 0.069$). Adjusted cell means are provided in Tables 40, 41 and 42.

TABLE 40

ANXIETY BY DEPENDENCY ADJUSTED CELL MEANS FOR KNOWLEDGE TOTAL

		Dependency		
		High	Low	Diff. H-L
Anxiety	High	50.69	49.47	1.22
	Low	48.60	51.56	-2.96
	Diff. H-L	2.09	-2.09	

number of subjects per cell = 42
Dunn's t (critical value) = 3.39 : $p \leq 0.10$

Post-hoc analysis yielded no significant differences ($p \leq 0.10$) among personality groups on knowledge total variable.

TABLE 41

ANXIETY BY DEPENDENCY ADJUSTED CELL MEANS FOR KNOWLEDGE POSTTEST TASK 2 (WEIGHT AFFECTS SPEED)

		Dependency		
		High	Low	Diff. H-L
Anxiety	High	51.91	49.26	2.65
	Low	48.03	51.24	-3.21
	Diff. H-L	*3.88	-1.98	

*$p \leq 0.10$
number of subjects per cell = 42
Dunn's t (critical value) = 3.82 : $p \leq 0.10$

The significant interaction with the Task 2 posttest indicates that the high anxious-high dependent student acquired a better knowledge level understanding of the concept--Weight Affects Speed--than the low anxious-high dependent student ($p \leq 0.10$); see Figure 5.

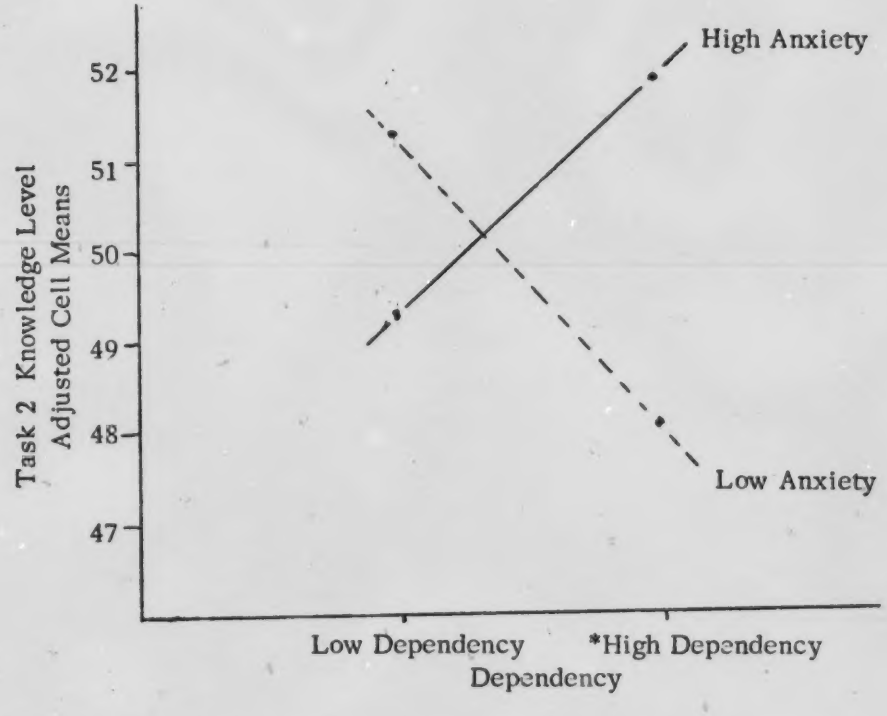


Figure 5. Interactive Effect of Anxiety by Dependency on the Task 2 Knowledge Level Posttest.

*significant $p \leq 0.10$

TABLE 42

ANXIETY BY DEPENDENCY ADJUSTED CELL MEANS FOR KNOWLEDGE POSTTEST TASK 3 (MASS AFFECTS MOTION)

		Dependency		
		High	Low	Diff. H-L
Anxiety	High	50.89	49.00	1.89
	Low	48.74	51.55	-2.81
	Diff. H-L	2.15	-2.55	

number of subjects per cell = 42
Dunn's t (critical value) = 3.56 : $p \leq 0.10$

Post-hoc analysis yielded no significant differences ($p \leq 0.10$) among personality groups on the Task 3 posttest.

First order interaction--Treatment by Dependency. The test of Treatment by Dependency for total process scores was included in Table 36. Table 43 presents the tests for the four science process subscale scores.

TABLE 43

TEST OF TREATMENT BY DEPENDENCY INTERACTIONS WITH THE FOUR SCIENCE PROCESS SUBSCALE SCORES

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	1.45	20.00	465.28	.095

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Inferring	1.52	106.23	.186
Predicting	1.00	70.36	.418
Inter. Data	1.77	119.06	.123
Id. Con. Var.	3.20	244.22	.009

Inspection of Tables 36 and 43 indicates that two-way interactions resulted for two variables: (1) total science process measure ($p \leq 0.075$); and (2) identifying and controlling variables ($p \leq 0.009$). Adjusted cell means are provided in Tables 44 and 45.

TABLE 44

TREATMENT BY DEPENDENCY ADJUSTED CELL MEANS FOR PROCESS TOTAL

Treatment	Dependency		
	High	Low	Diff. H-L
A	47.91	48.58	-0.67
B	55.41	50.53	4.88
C	49.28	50.31	-1.03
D	51.55	49.99	1.56
E	48.52	51.25	-2.73
F	53.14	44.75	*8.39

* $p \leq 0.05$
number of subjects per cell = 14
Dunn's t (critical value) = 7.60: $p \leq 0.05$

The two-way interaction occurred at Treatment F ($p \leq 0.05$) in which the high dependent student was more successful and the low dependent student less successful on the total science process measure; see Figure 6.

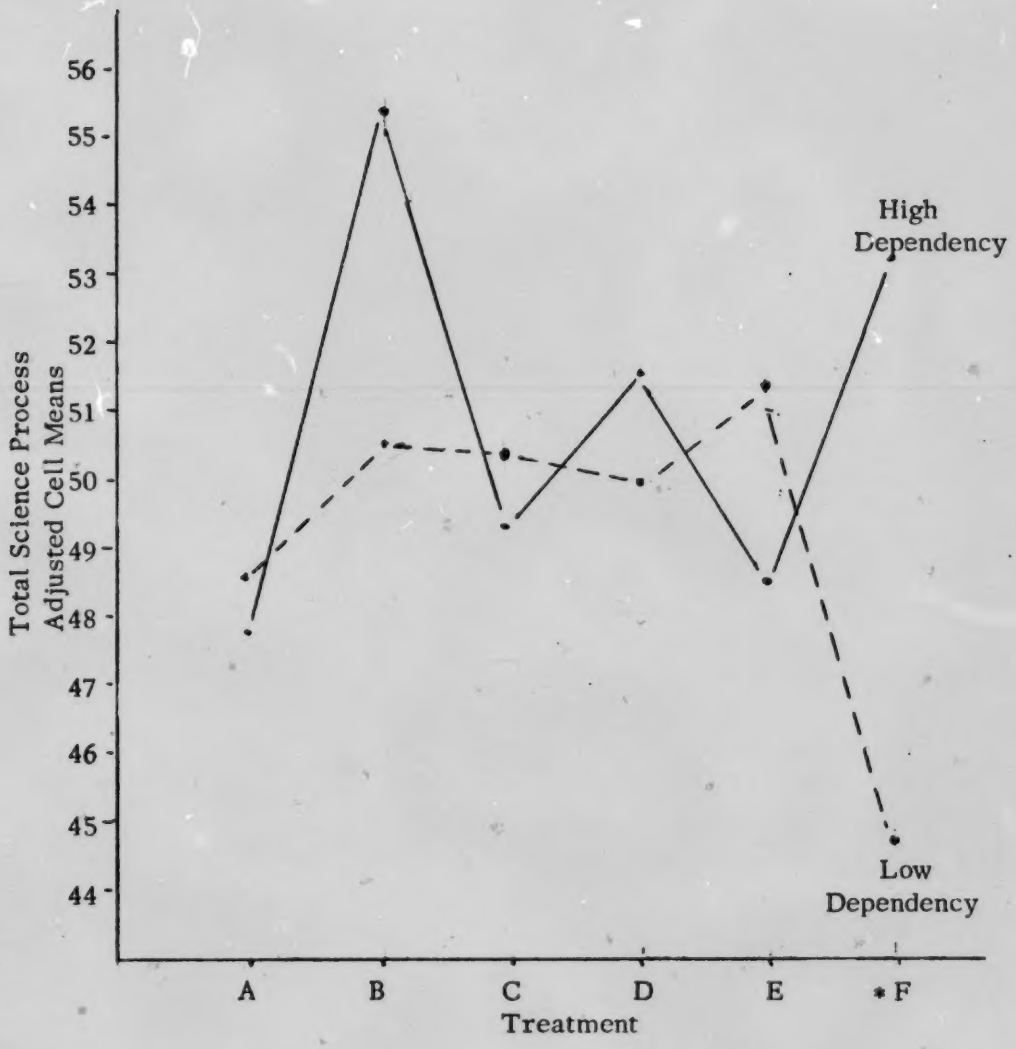


Figure 6. Interactive Effect of Treatment by Dependency on the Total Science Process Measure.

*significant $p \leq 0.05$

TABLE 45

TREATMENT BY DEPENDENCY ADJUSTED CELL MEANS FOR THE SCIENCE PROCESS SKILL--IDENTIFYING AND CONTROLLING VARIABLES

Treatment	Dependency		
	High	Low	Diff. H-L
A	47.12	50.19	-3.07
B	53.94	51.30	2.64
C	49.00	51.65	-2.65
D	52.48	47.82	4.66
E	49.88	52.24	-2.36
F	53.86	41.74	*12.12

*$p \leq 0.05$
number of subjects per ceil = 14
Dunn's t (critical value) = 8.61 : $p \leq 0.05$

The two-way interaction occurred at Treatment F ($p \leq 0.05$) where it was found that the high dependent student was more successful and/or the low dependent student was less successful in acquiring the process skill; see Figure 7.

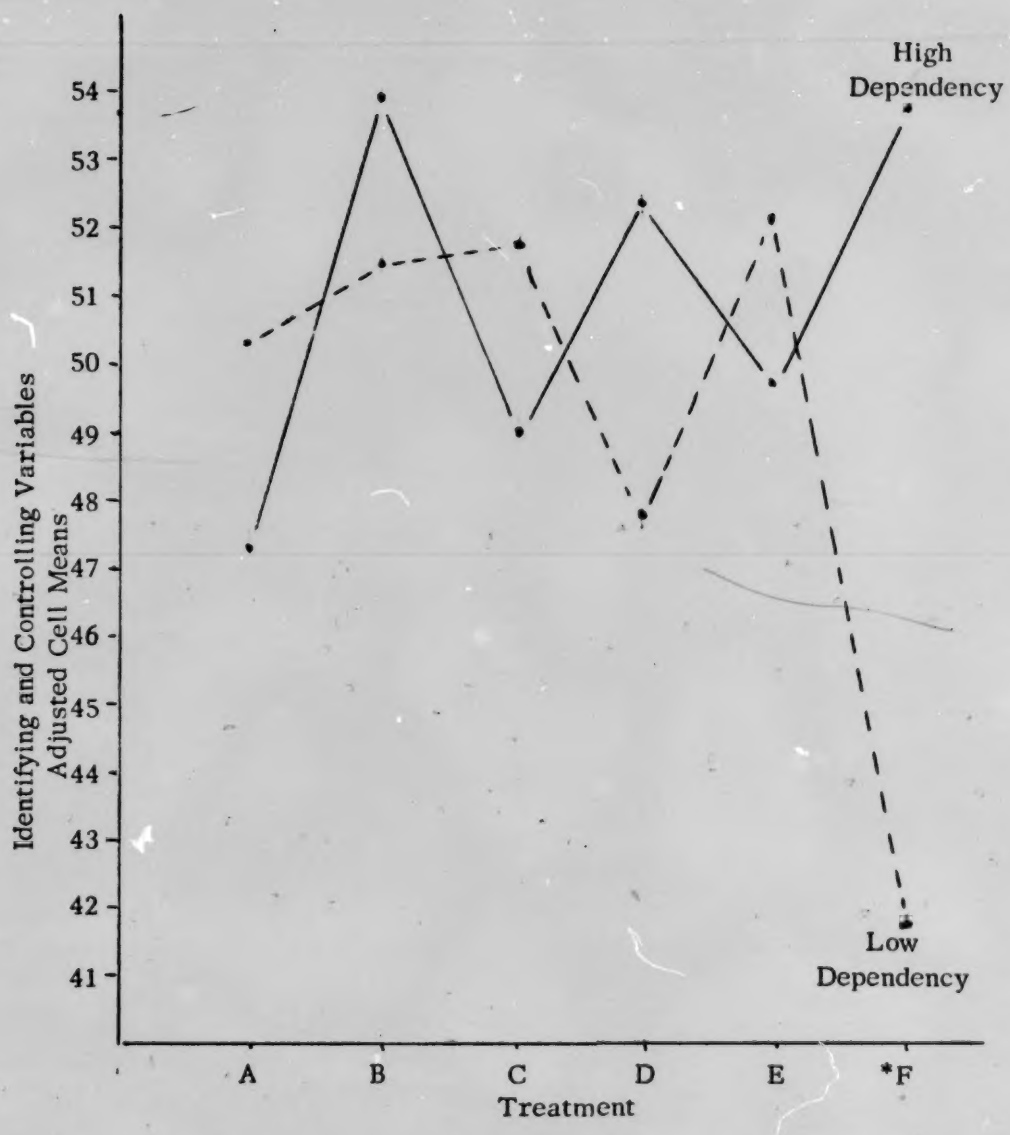


Figure 7. Interactive Effect of Treatment by Dependency on the Identifying and Controlling Variables Measure

*significant $p \leq 0.05$

First order interaction--Anxiety by Dependency. The results of Anxiety by Dependency analysis for the total process measure were provided in Table 38. Table 46 presents the MANCOVA for the four science process subscale scores.

TABLE 46

TEST OF ANXIETY BY DEPENDENCY INTERACTIONS WITH THE FOUR SCIENCE PROCESS SUBSCALE SCORES

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.61	4.00	140.00	.176

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Inferring	6.14	427.99	.014
Predicting	2.43	170.26	.121
Inter. Data	1.41	95.16	.237
Id. Con. Var.	2.58	196.50	.111

Inspection of Tables 38 and 46 indicates that two-way interactions resulted for three variables: (1) total science process measure ($p \leq 0.033$); (2) inferring ($p \leq 0.014$); and (3) identifying and controlling variables ($p \leq 0.111$). Adjusted cell means are presented in Tables 47, 48 and 49.

TABLE 47

ANXIETY BY DEPENDENCY ADJUSTED CELL MEANS FOR PROCESS TOTAL

		Dependency		
		High	Low	Diff. H-L
Anxiety	High	52.68	48.37	*4.31
	Low	49.25	50.10	-0.85
	Diff. H-L	3.43	-1.73	

*$p \leq 0.05$
number of subjects per cell = 42
Dunn's t (critical value) = 4.20 : $p \leq 0.05$

The two-way interaction for the total science process variable occurred with anxiety ($p \leq 0.05$) where it was found that the high dependent student was more positively affected by high anxiety and/or the low dependent student was more negatively affected by high anxiety; see Figure 8.

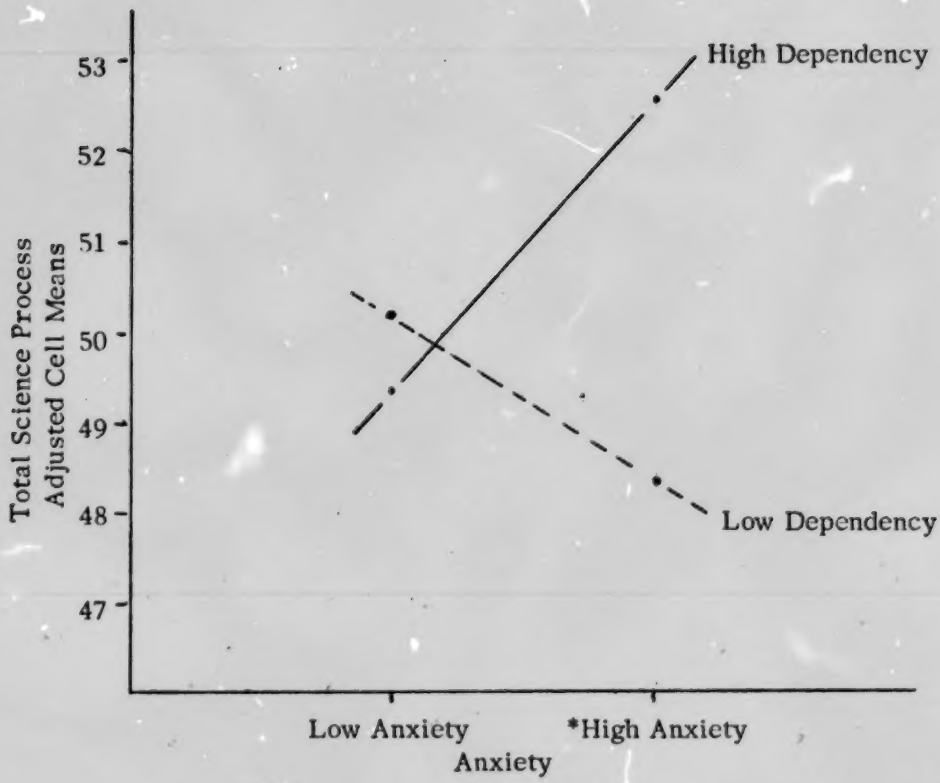


Figure 8. Interactive Effect of Anxiety by Dependency with Total Science Process Measure.

*significant $p \leq 0.05$

Figure 8 indicates that as Anxiety increased, the performance of the high dependent subject improved relative to that of the low dependent subject.

TABLE 48

ANXIETY BY DEPENDENCY ADJUSTED CELL MEANS FOR INFERRING

		Dependency		
		High	Low	Diff. H-L
Anxiety	High	53.29	47.98	*5.31
	Low	48.98	50.09	-1.11
	Diff. H-L	**4.31	-2.11	

*$p \leq 0.05$
**$p \leq 0.10$
number of subjects per cell = 42
Dunn's t (critical values) = 4.58 and 4.19 : $p \leq 0.05$ and $p \leq 0.10$ respectively

Two-way disordinal interaction ($p \leq 0.10$) resulted with the science process skill of inferring where it was found that the high anxious-high dependent student had significantly higher inferring scores than the high anxious-low dependent student and the low anxious-high dependent student; see Figures 9 and 10.

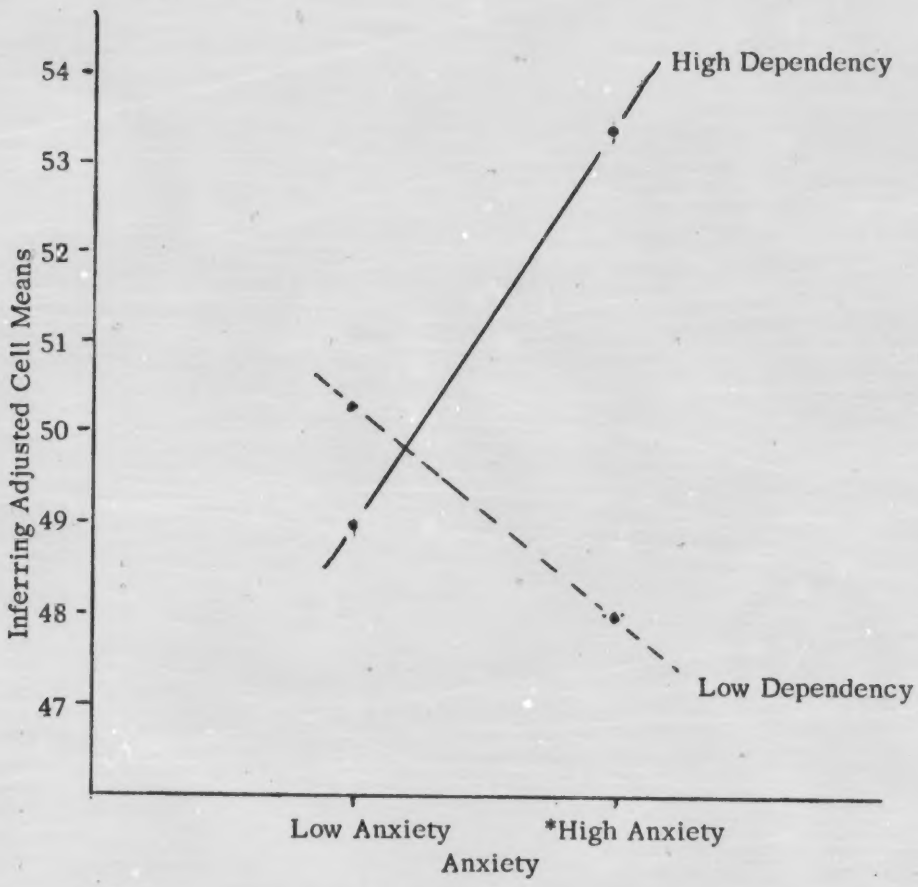


Figure 9. Interactive Effect of Anxiety by Dependency with the Inferring Measure.

*significant $p \leq 0.05$

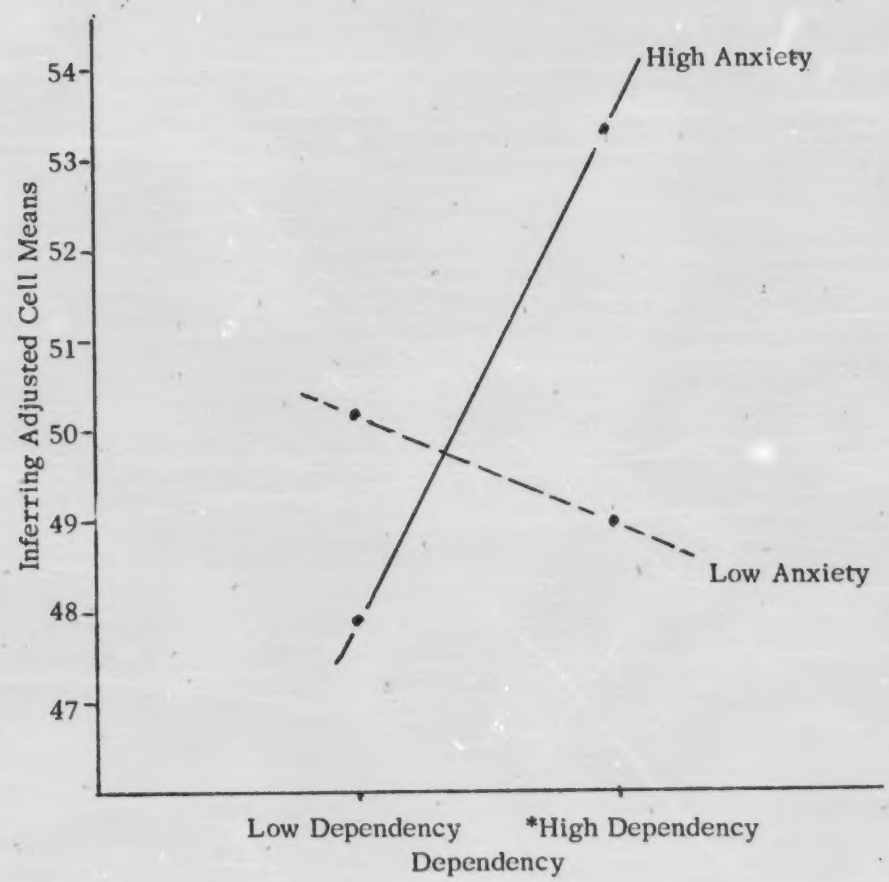


Figure 10. Interactive Effect of Dependency by Anxiety with the Inferring Measure.

*significant $p \leq 0.10$

TABLE 49

ANXIETY BY DEPENDENCY ADJUSTED CELL MEANS FOR IDENTIFYING AND CONTROLLING VARIABLES

		Dependency		
		High	Low	Diff. H-L
Anxiety	High	51.74	47.68	*4.06
	Low	50.35	50.64	-0.29
	Diff. H-L	1.39	-2.96	

*$p \leq 0.10$
number of subjects per cell = 42
Dunn's t (critical value) = 3.76 : $p \leq 0.10$

Table 49 indicates that the high anxious-high dependent student had significantly higher identifying and controlling variable scores than the high anxious-low dependent student. Adjusted cell means are plotted in Figure 11.

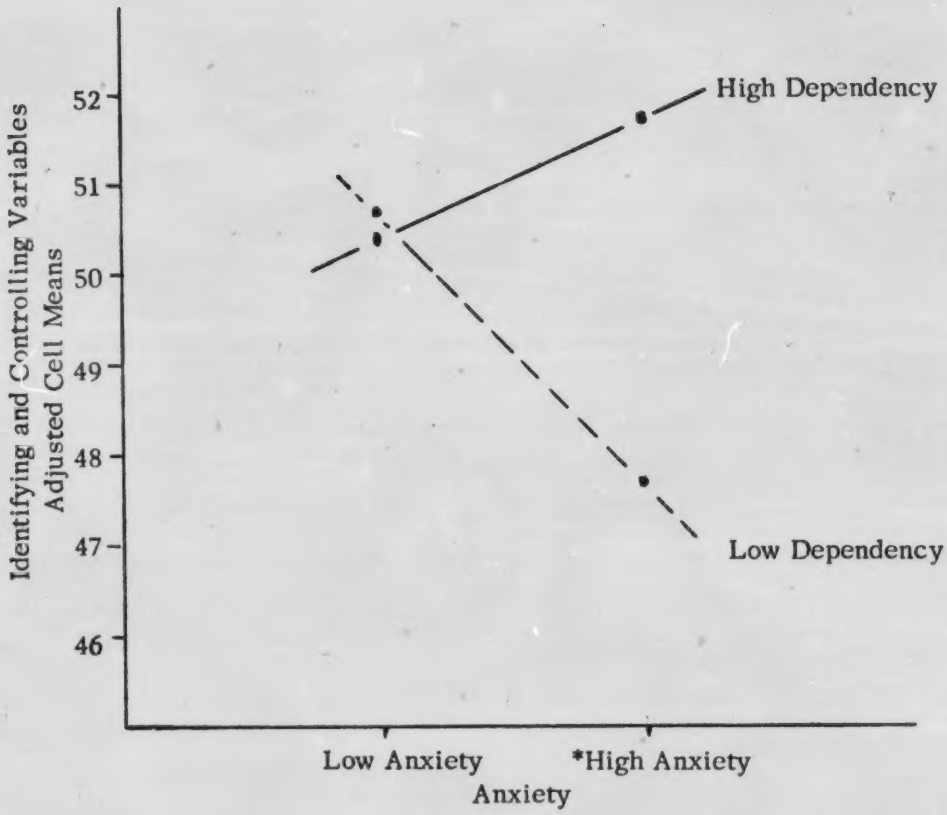


Figure 11. Interactive Effect of Anxiety by Dependency with the Identifying and Controlling Variables Measure.

*significant $p \leq 0.10$

Hypotheses V, VI, VII, VIII, IX and X: Main Effects. The hypothesis (V) that there are no significant differences in the adjusted means for the knowledge level variables between levels of Anxiety was not rejected ($p \leq 0.10$).

The hypothesis (VI) that there are no significant differences in the adjusted means for the science processes level variables between levels of Anxiety was not rejected ($p \leq 0.10$).

The hypothesis (VII) that there are no significant differences in the adjusted means for the knowledge level variables between levels of Dependency was rejected. Significant main effects ($p \leq 0.061$) resulted with the Task 4 posttest (Mass Affects Momentum).

The hypothesis (VIII) that there are no significant differences in the adjusted means for the science processes variables between levels of Dependency was not rejected ($p \leq 0.10$).

The hypothesis (IX) that there are no significant differences in the adjusted means for the knowledge level variables between levels of Teaching Structure was rejected. Significant main effects ($p \leq 0.007$) resulted with the Task 3 posttest (Mass Affects Motion).

The hypothesis (X) that there are no significant differences in the adjusted means for the science processes level variables between levels of Teaching Structure was not rejected ($p \leq 0.10$). MANCOVA tables, adjusted raw means, and standard deviations for the tests of hypotheses V, VI, VIII, and X are available in Appendix F.

Main effects--Dependency. The test of Dependency main effects with the five knowledge level posttests is presented in Table 50.

TABLE 50

TEST OF DEPENDENCY MAIN EFFECTS WITH THE FIVE KNOWLEDGE LEVEL POSTTESTS

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.23	5.00	139.00	.300

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Know Task 1	.03	1.82	.875
Know Task 2	.04	3.14	.842
Know Task 3	.13	8.82	.719
Know Task 4	3.55	313.93	.061
Know Task 5	.48	40.18	.491

Table 50 indicates that significant main effects ($p \leq 0.061$) resulted for the Task 4 (Mass Affects Momentum) posttest. The multivariate test of main effects was not significant; hence, caution should be exercised when interpreting univariate tests. It appears that performance differed from Task 1 to Task 5. Adjusted cell means are provided in Table 51.

TABLE 51

ADJUSTED MEANS OF TASK 4 (MASS AFFECTS MOMENTUM) POSTTEST SCORES BY DEPENDENCY GROUPS

Dependency		
High	Low	Diff. H-L
48.53	51.30	-2.77

*$p \leq 0.061$
number of subjects per cell = 84

Inspection of Table 51 indicates the low dependent student acquired a significantly better understanding of the Task 4 concept (Mass Affects Momentum) than the high dependent student.

Main effects--Teaching Structure. The test of Teaching Structure/ Treatment main effects with the five knowledge level posttests is presented in Table 52.

TABLE 52

TEST OF TREATMENT MAIN EFFECTS WITH THE FIVE KNOWLEDGE LEVEL POSTTESTS

Multivariate Tests of Significance Using Wilks Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.15	25.00	517.86	.285

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Know Task 1	.74	54.60	.594
Know Task 2	.58	45.44	.715
Know Task 3	3.33	226.66	.007
Know Task 4	.52	46.05	.760
Know Task 5	1.44	121.19	.214

Significant main effects ($p \leq 0.007$) resulted for the Task 3 (Mass Affects Motion) knowledge level posttest. The multivariate test of main effects was not significant; hence, caution should be exercised when interpreting univariate tests. Adjusted cell means comparisons are provided in Table 53.

TABLE 53

ADJUSTED MEAN COMPARISON MATRIX OF TASK 3 (MASS AFFECTS MOTION) POSTTEST SCORES BY TREATMENT GROUPS

		Teaching Structure					
Treatment Means - Diff. H-L		A 51.83	B 54.60	C 49.86	D 47.01	E 49.69	F 47.27
A	51.83		-2.77	1.97	4.82	2.14	4.56
B	54.60			4.74	*7.59	4.91	*7.33
C	49.86				2.85	.17	2.59
D	47.01					-2.68	-.26
E	49.69						2.42
F	47.27						

*$p \leq 0.05$
number of subjects per cell = 28
Dunn's t (critical value) = 6.47 : $p \leq 0.05$

The significant main effect ($p \leq 0.05$) occurred with the Task 3 measure where it was found that students assigned to the more structured Treatment Group B acquired the concept (Mass Affects Motion) better than students assigned to the less structured Treatments D and F.

Summary of Main Study Results. Table 54 provides a listing of significant findings.

TABLE 54

SUMMARY OF MAIN STUDY MANCOVA RESULTS

Interactions and Main Effects	Tests of Significance	Post-hoc Analyses	P Less Than
3 Way Know. T x A x D[a]			
Multivariate (M)	NSD[b]		
Univariate (U)	NSD		
3 Way Process T x A x D			
Multivariate	NSD		
Univariate	NSD		
2 Way Know. Variables			
T x A			
(M) 5 Know. Posttests	$p \leq 0.054$		
(U) Task 1	$p \leq 0.085$	NSD	
T x D			
(U) Know. Total	$p \leq 0.090$	LD>HD at Treatment E	0.10
A x D			
(U) Know. Total	$p \leq 0.088$	NSD	
(U) Task 2	$p \leq 0.035$	HAHD>LAHD	0.10
(U) Task 3	$p \leq 0.069$	NSD	
2 Way Process Variables			
T x D			
(U) Process Total	$p \leq 0.075$	HD>LD at Treatment F	0.05
(U) Id. Con. Var.	$p \leq 0.009$	HD>LD at Treatment F	0.05
A x D			
(U) Process Total	$p \leq 0.033$	HAHD>HALD	0.05
(U) Inferring	$p \leq 0.014$	HAHD>HALD	0.05
(U) Inferring	$p \leq 0.014$	HAHD>LAHD	0.10
(U) Id. Con. Var.	$p \leq 0.111$	HAHD>HALD	0.10
Main Effects Know. Var.			
D			
(U) Task 4	$p \leq 0.061$	LD>HD	
T			
(U) Task 3	$p \leq 0.007$	T-B >T-D and T-F	0.05

[a]T x A x D refers to levels of Teaching Structure, levels of Anxiety and levels of Dependency

[b]NSD = no significant differences

The two-way multivariate interaction between Teaching Structure (T) and Anxiety (A) with the five knowledge level posttests suggests that student anxiety affects performance when varying amounts of teacher guidance are provided. The distributions of adjusted cell means for Tasks 1 and 2 were similar; that is, high anxiety students performed better in the more structured Treatments (A-C) as compared with the low dependent students and the low dependent students performed better than the high anxiety students in the less structured Treatments (D-F). There seems to be little similarity between adjusted cell means patterns (Figure 2 and 3) for Tasks 3, 4 and 5 and those resulting for Tasks 1 and 2, or among Tasks 3, 4 and 5. In addition, erratic performance across Treatments within levels of Anxiety was also suggested. A plausible explanation is that the effects of Anxiety diminished after students experienced Tasks 1 and 2. A two-way interaction ($p \leq 0.085$) resulted only for Task 1 presented on Day 1 of the instructional session. The evidence is supportive of this explanation of the multivariate interaction.

The two-way interaction ($p \leq 0.090$) between Teaching Structure and Dependency with the knowledge total measure indicated that the low dependent subjects performed better than the high dependent subjects at Treatment E (low Teaching Structure). Performance was similar between Dependency groups in the more structured Treatments. Treatment by Dependency two-way interactions also occurred with two science process level variables: (1) total science process measure; and (2) identifying and controlling variables measure. High Dependent students were more successful than low

Dependent students at Treatment F (minimal Teaching Structure) with both variables. It appears that dependency affects student performance: (1) more with less teaching structure; and (2) differently with varied levels of concept understanding (i.e., knowledge and process).

The anxiety and dependency constructs interacted with the acquisition of science knowledge and processes as presented in Table 54. Each characteristic has positive and negative aspects (pp. 8, 12-16). In regard to this study, it seems that the positive aspects of high anxiety were enhanced by high dependency, more so than other combinations of characteristics. It seems that the negative aspects of low anxiety are compounded by high dependency. In addition, the negative aspects of high anxiety seem to be amplified by low dependency.

The Dependency and Treatment main effects seem to imply that student performance varied by Tasks. A more detailed presentation of significant findings is available in Chapter V.

CHAPTER V

SUMMARY, DISCUSSION OF RESULTS, CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

This chapter is developed under five subheadings: a summary of the study, discussion of results, conclusions, implications, and recommendations for future research.

Summary of the Study

This study investigated the relationships of student anxiety and dependency to the effects of teaching structure on the acquisition of science knowledge and processes within inductive/discovery learning.

This aptitude-treatment-interaction (ATI) study involved fifth and sixth grade students in two suburban elementary schools. The sample was stratified using the personological variables of anxiety and dependency. The treatment consisted of varying degrees of teacher and/or student control within inductive/discovery learning. Five correlational concepts, one for each instructional task, from within the conceptual scheme--force--were included as science content. To account for the influence of structure in inductive/discovery methods, both knowledge and process measures were used. Knowledge level dependent variables included one ten question posttest for each of the five concepts: (1) Height Affects Impact Force; (2) Weight

Affects Speed; (3) Mass Affects Motion; (4) Mass Affects Momentum; and (5) Weight Affects the Force of Friction. The composite of the five knowledge level posttests was also considered a dependent variable. Science process level dependent variables included: (1) total scores for the Test of Science Inquiry Skills; and (2) four subscores (inferring, predicting, interpreting data and identifying and controlling variables). Ankney-Joyce Reasoning Test scores were used as a covariate to reduce student differences attributable to varied levels of cognitive development. The resulting data were analyzed in a 2 x 2 x 6 multivariate analysis of covariance design with the aforementioned dependent variables and covariate.

The study took place during the Autumn, Winter, and Spring Quarters of the 1976-1977 school year at The Ohio State University. A review of the literature and comments by several faculty members of The Ohio State University suggested that interpretation of the results may be confounded by: (1) innate differences in science knowledge and science process skills among four personality groups; (2) amount of time that the students handled equipment; (3) student's level of expectation; (4) differences in socio-economic status; and (5) differences in cognitive development.

The students included in the pilot and main studies were given the Children's Manifest Anxiety Scale, a Dependence Proneness Scale, and the Ankney-Joyce Reasoning Test. Subjects were classified as high or low for anxiety and dependency relative to the distribution of the sample and randomly assigned to treatment. In regard to the main study, a score of 18 (sample

median) was used to place a student in the high half of the High-Low Anxiety continuum. A score of 76 (sample median) was used to place a student in the high half of the High-Low Dependency continuum.

A pilot study was conducted during Winter Quarter 1977 at an elementary school in the Mansfield, Ohio, area. Results indicated that no significant differences on science knowledge and processes measures existed prior to treatment among the four personality groups, and that differences in amount of time in handling equipment by treatment were not significant. Pilot study results also aided in the refinement of instructional tasks, pretreatment information, and instruments.

Main study data were gathered for students from two Columbus area suburban elementary schools (Spring Quarter 1977). After treatment group membership was established, seven students per personality group per treatment were scheduled to one of three instructional sessions. Each session consisted of an instructional sequence (five tasks, one/day). Worksheets were used to regulate the amount of teaching structure. Teaching structure refers to the relative amounts of teacher and/or student control within each of the instructional tasks. Knowledge level data were gathered after each of five instructional periods. The science processes level data were gathered in a large group setting on the days following the completion of each of three instructional sessions. Instruction groups (approximately twelve students/class) were formed to reduce the possibility of a class-treatment interaction. Awards for participation and high achievement served to standardize students'

level of expectation.

The confounding effects of differences in socio-economic level were reduced by randomization and by including students from only one suburban school district. It was assumed that such differences would be less in a relatively small suburban district than in a larger urban district. Pretreatment information was presented prior to each task to minimize student differences attributable to varied content background and grade levels.

The Concept Component Pretest and the Test of Science Inquiry Skills were administered to twenty-eight subjects (seven from each personality group) to identify differences among personality groups prior to treatment. Significant main effects ($p \leq 0.10$) resulted for the inferring and process total variables between levels of dependency when the data were analyzed without the covariate. However, no significant differences resulted with the covariate. It appears that the covariate reduced pretreatment differences among personality groups. Other potential confounding variables were controlled by randomization.

Discussion of Results

This section is organized by null hypotheses. Three-way interactions are presented first followed by two-way interactions and main effects. Results are stated with each hypothesis. Related research is presented in the same sequence as the results under the hypotheses.

Hypotheses I and II: Three-way Interactions. The hypothesis that there are no significant three-way interactions in the knowledge level variables between levels of Teaching Structure, levels of Anxiety, and levels of Dependency was not rejected ($p \leq 0.10$).

The hypothesis that there are no significant three-way interactions in the science processes level variables between levels of Teaching Structure, levels of Anxiety, and levels of Dependency was not rejected ($p \leq 0.10$).

It appears that the knowledge and process understanding of the students is not differentially affected by the combination of Anxiety-Dependency levels and Teaching Structure.

Hypotheses III and IV: Two-way Interactions. The hypothesis that there are no significant two-way interactions in the knowledge level variables between levels of Teaching Structure, levels of Anxiety or levels of Dependency was rejected. A multivariate two-way interaction ($p \leq 0.10$) resulted between levels of Teaching Structure (T) and Anxiety (A) with the five knowledge post-tests. A univariate T x A interaction ($p \leq 0.10$) resulted only with posttest Task 1 (Height Affects Impact Force). Other univariate two-way interactions ($p \leq 0.10$) occurred between levels of: (1) Teaching Structure and Dependency with the composite of knowledge level posttest scores; and (2) Anxiety and Dependency with the composite of the knowledge level posttest scores and the Tasks 2 and 3 knowledge level posttests.

The hypothesis that there are no significant two-way interactions in the science processes level variables between levels of Teaching Structure,

levels of Anxiety or levels of Dependency was rejected. Two-way interactions ($p \leq 0.10$) resulted between levels of: (1) Teaching Structure and Dependency with the scores from the total science process measure and with the science process skill of identifying and controlling variables subscores and (2) Anxiety and Dependency with the scores on the total science process measure and with subscores on the science process skills of inferring and identifying and controlling variables measures.

First order multivariate and univariate interactions--Treatment by Anxiety. Research conducted by Gaudry and Spielberger (1971), Grimes and Allinsmith (Rosenblith and Allinsmith, eds., 1962) indicated that high anxious subjects performed better with more structured teaching methods. Tallmadge and Shearer (1971) found that high anxious students scored significantly higher than low anxious students with a less structured teaching method.

Spielberger (1972) discussed anxiety both as a personality trait and an emotional state. Persons with anxiety as a personality trait tend to experience more frequent and intense anxiety states (p. 31). Trait anxiety was measured by the Children's Manifest Anxiety Scale in this study. It seems likely that the high anxiety subjects experienced a more intense anxiety state on the first day of the instructional session than on Days 2-5 when they were more familiar with the requirements and general format of the activities. This explanation seems to be supported by the Treatment by Anxiety interaction occurring only with Task 1 posttest scores collected on Day 1 of the

instructional sessions. When the effects of anxiety are manifested, they may affect student acquisition of science knowledge differentially at various levels of teaching structure. High anxious students performed better than low anxious students in the more structured treatments and the low anxious students performed better than the high anxious students in the less structured treatments as indicated by the pattern of adjusted cell means resulting for Tasks 1 and 2. No such consistent differences resulted with Tasks 3, 4 and 5.

First order interaction--Treatment by Dependency. Domino (1971) and Tuckman (1969) found that the less dependent student achievement was differentiated in favor of nondirective/less structured teaching. Science processes were not criteria in either study. In the present study the significant interaction ($p \leq 0.10$) occurred at Treatment E (low Teaching Structure), where it was found that low dependent student performance was better than that of the high dependent student as measured by the composite of the five knowledge level posttests. Subjects assigned to Treatment E received Task Components 1 and 2 (i.e., Area of Investigation and Arrangement of Equipment). Minimal structure (Treatment F) seemed to have a negative effect on low dependency student performance. Moderately low teaching structure seemed to have enhanced science knowledge level achievement of low dependent students relative to that of high dependent students.

First order interaction--Anxiety by Dependency. The two-way interaction ($p \leq 0.10$) with the Task 2 posttest indicated that high anxiety-high dependent students acquired a better knowledge level understanding of the

concept--Weight Affects Speed--than did low anxiety-high dependent students ($p \leq 0.10$). It seems that the positive characteristics of high anxiety were enhanced by high dependency and/or the negative characteristics of low anxiety were compounded by high dependency in regard to Task 2 knowledge level understanding. Characteristics of the anxiety and dependency groups are presented with the discussion of the Anxiety by Dependency interactions for the science processes variables.

First order interaction--Treatment by Dependency. Science process criteria, teaching structure and dependency, were included in a study by Crocker, Bartlett and Elliot (1976). They did not obtain Treatment by Dependency interactions, possibly due to the occurrence of a class-treatment interaction. In the present study, two-way interactions ($p \leq 0.05$) resulted for the science process total and identifying and controlling variables measures. High Dependent students were more successful than low Dependent students at Treatment F (minimal Teaching Structure) with both variables. When subjects' dependency scores were analyzed (Chapter IV), it was noted that the greatest difference between dependency means across levels of Teaching Structure occurred at Treatment F. The average difference between levels of dependency at Treatments A-E was 13.93, while the difference between means at Treatment F was 22.00. It seems that when mean differences between levels of dependency are relatively large, high dependent students are more successful with minimal teacher guidance than are low dependent students in science process total and identifying and controlling variables achievement. These

findings are not consistent with the knowledge level results obtained in this study or in studies reported by Domino (1971) and Tuckman (1969). An explanation of the differences in the knowledge level and process level performance by low dependent students in less structured treatments is not possible at this time.

First order interactions--Anxiety by Dependency. McCandless and Evans (1967) and Levitt (1967) suggested that moderate levels of anxiety enhance performance on a variety of cognitive tasks. According to Flanders (1961), high dependent students exhibit a strong need for teacher approval.

In this study, two-way interactions resulted for three variables: (1) science processes measure ($p \leq 0.033$); (2) inferring ($p \leq 0.014$); and (3) identifying and controlling variables ($p \leq 0.111$). It was found that the High Anxiety-High Dependency (HAHD) subjects were more successful than the High Anxiety-Low Dependency (HALD) subjects on each of the three criteria. In addition, the High Anxiety-High Dependency subjects were more successful than the Low Anxiety-High Dependency (LAHD) subjects on the inferring measure. It appears that the effects of moderately high anxiety combined with the need for teacher approval (high dependency) tend to enhance the achievement of certain science processes relative to the achievement of the HALD and LAHD groups.

Hypotheses V, VI, VII, VIII, IX and X: Main Effects. The hypothesis (V) that there are no significant differences in the adjusted means for the knowledge level variables between levels of Anxiety was not rejected

($p \leq 0.10$).

The hypothesis (VI) that there are no significant differences in the adjusted means for the science processes level variables between levels of Anxiety was not rejected ($p \leq 0.10$).

The hypothesis (VII) that there are no significant differences in the adjusted means for the knowledge level variables between levels of Dependency was rejected. Significant main effects ($p \leq 0.061$) resulted with the Task 4 posttest (Mass Affects Momentum).

The hypothesis (VIII) that there are no significant differences in the adjusted means for the science processes variables between levels of Dependency was not rejected ($p \leq 0.10$).

The hypothesis (IX) that there are no significant differences in the adjusted means for the knowledge level variables between levels of Teaching Structure was rejected. Significant main effects ($p \leq 0.007$) resulted with the Task 3 posttest (Mass Affects Motion).

The hypothesis (X) that there are no significant differences in the adjusted means for the science processes level variables between levels of Teaching Structure was not rejected ($p \leq 0.10$).

Main effects--Dependency. Significant main effects ($p \leq 0.061$) resulted for Task 4 (Mass Affects Momentum) posttest, where it was found that the low dependent students acquired a better understanding of the concept than did the high dependent students. Raven (1967-68) described momentum as having mass and speed as subcomponents. Momentum may be more complex

than other concept components which suggests the possibility of task specific effects. The results seem to indicate that low dependency enhanced student knowledge level understanding relative to that of the high dependency trait on one task and this task may be relatively complex.

Main effects--Teaching Structure. Significant main effects ($p \leq 0.007$) resulted for the Task 3 (Mass Affects Motion) where it was found the performance at Treatment B (moderately high Teaching Structure) was superior to performance at two less structured treatments (D and F). The occurrence of main effects for only one task suggests the effects of Teaching Structure varied by task. Item analyses for the five knowledge posttests (Chapter III) indicated that the mean item difficulty of Task 3 was larger than that of other tasks. The effects of Teaching Structure were maximized with student knowledge level understanding of one concept and this concept may have been relatively difficult.

Conclusions

Generalizations from this study are limited by the accuracy of data interpretations and by the population's characteristics. The results of this study seem to support the following conclusions:

1. The high anxiety individuals gain more knowledge when teaching is highly structured.

2. The literature and this study are contradictory for the influence of teaching structure on the learning of knowledge by individuals of high anxiety

versus low anxiety.

3. There is some evidence that low dependent individuals perform better with low teaching structure.

4. The person who is both high in anxiety and high in dependency does better on both the knowledge and process levels of achievement.

5. Overall, low dependency individuals do better on more complex tasks.

6. Overall, a high degree of teaching structure is better for difficult tasks.

Implications

1. The Children's Manifest Anxiety Scale and the Dependency Proneness Scale are quite practical for use with inservice and preservice teachers. The instruments are easily obtained, duplicated, administered and scored. The identification of student anxiety and dependence proneness is of value to the teacher concerned with matching science subject matter with the special requirements and capabilities of each learner. The results of this study suggest that science knowledge achievement can be enhanced by matching: (1) the high anxious students with a more structured teaching method; and (2) the low dependent students with a less structured teaching method.

2. Differences in student dependence proneness may be a relevant consideration in instructional decision making, particularly when the teacher is concerned with determining the optimum amount of teacher and/or student control (teaching structure) within a class activity or an instructional

sequence. Dependence proneness may be a factor in determining success in the acquisition of science knowledge and processes, especially when less teaching structure is provided. The effects of teaching structure and dependency may vary with the expected level of concept understanding (LD > HD at moderately low teaching structure with the knowledge total criterion; HD > LD at minimal teaching structure with the process total and the identifying and controlling variables criteria).

3. The instructional tasks developed for this study may be used by fifth and sixth grade teachers to present selected concepts from within the conceptual scheme--force.

4. Anxiety and Dependency appear to be factors in determining success in the acquisition of science knowledge and processes within inductive/discovery learning, particularly among the High Anxiety-High Dependency, the Low Anxiety-High Dependency, and High Anxiety-Low Dependency personality groups. Across the six levels of Teaching Structure, the HAHD group learned more science knowledge and processes than the other personality groups. Special attention (supplementary materials, etc.) may be required to more adequately meet the unique needs of LAHD and HALD students.

5. The significant correlations ($p \leq 0.001$) between Ankney-Joyce Reasoning Test scores and the scores on the science knowledge and processes criteria used in this study suggest that reasoning ability may be a factor in determining success in the learning of science knowledge and processes within inductive/discovery learning.

6. Task specific characteristics (e.g., complexity and difficulty) should be considered by the researcher concerned with science concept understanding, especially at the knowledge level (Bloom, 1956). Task complexity refers to the number of concept dimensions or components. Task difficulty refers to the proportion of students not correctly answering items testing a specific concept. Literature cited in Chapter II suggests that a complex concept may be less difficult to learn than a simple concept (i.e., one dimension) providing the complex concept fits the child's cognitive level while the simple concept does not.

Recommendations for Future Study

1. This research indicated that reasoning ability (AJRT) was significantly correlated ($p \leq 0.001$) with students' science knowledge and processes achievement. It is suggested that similar research be done by using reasoning test scores as a blocking variable. This new research would aid in the identification of the relationships of student reasoning ability to the effects of teaching structure on the learning of science knowledge and processes within inductive/discovery learning.

2. Additional research is needed to more adequately explain the relationships of student anxiety to the effects of teaching structure on the learning of science knowledge and processes within inductive/discovery learning. Such a study may be facilitated by: (1) limiting participation to subjects with manifest anxiety scores in the upper and lower quarters of the sample distribution such that the differences between high and low anxiety are relatively large;

and (2) limiting the number of tasks to one, thus reducing the possibility of diminished anxiety effects due to extended task experience.

3. Correlational concepts were included in this research; perhaps a similar study should be conducted which would include classificational (e.g., insect) and/or theoretical (e.g., atom) concepts as science content.

4. In the review of the literature, gains in critical thinking, knowledge of scientific methodology, and ability to perform in the laboratory were attributed to inductive/discovery learning. It is recommended that measures of critical thinking, knowledge of scientific methodology, and ability to perform in the laboratory be included as dependent variables in studies involving instruction. These in conjunction with personological variables would contribute to a theory of individual differences and inductive/discovery learning.

5. Since this study used worksheets as a method of imposing teaching structure, it is suggested that similar research be made without worksheets and with two treatments: (1) high teaching structure imposed by the arrangement of equipment; and (2) low teaching structure being imposed by equipment randomly placed about the laboratory station. This is essentially the difference between Treatments E and F. This recommendation is supported by the occurrence of significant differences between levels of Dependency at Treatments E and F. This procedure may strengthen treatment effects and thereby improve the possibility of obtaining three-way interactions. A three-way interaction would provide the researcher with insight concerning the differential effects of teaching structure by personality groups on the

learning of science knowledge and processes within inductive/discovery learning.

BIBLIOGRAPHY

Anderson, O. Roger. "Research on Structure in Teaching," Journal of Research in Science Teaching, XI, 3(1974), 219-230.

Ankney, Paul and Joyce, Lyle. "The Development of a Piagetian Paper-and-Pencil Test for Assessing Concrete Operational Reasoning." Doctoral Dissertation, The University of Northern Colorado, 1974.

Ausubel, David P. "Learning By Discovery: Rationale and Mystique," Bulletin: National Association of Secondary Principals, XLV (1961), 18-58.

_____. The Psychology of Meaningful Verbal Learning. New York: Grune and Stratten, Inc., 1963.

_____. "Some Psychological Considerations in the Objectives and Design of an Elementary School Program," Science Education, XLVII (1963), 278-284.

_____. "Some Psychological and Educational Limitations of Learning by Discovery." The Arithmetic Teacher, XV (1964), 291-302.

Babikian, Yeghia. "An Empirical Investigation to Determine the Relative Effectiveness of Discovery, Laboratory and Expository Methods of Teaching Science Concepts," Journal of Research in Science Teaching, VIII, 3(1971), 201-209.

_____. "Author's Reply," Journal of Research in Science Teaching, X (1973), 176-178, reply to Milton Ignatz, Jr., "Commentary on 'An Empirical Investigation to Determine the Relative Effectiveness of Discovery, Laboratory, and Expository Methods of Teaching Science Concepts'," Journal of Research in Science Teaching, X (1973), 175-176.

Ball, Daniel Wayne, and Sayre, Steven A. "Relationship Between Student Piagetian Cognitive Development and Achievement in Science," Dissertation Abstracts, XXXIII, 3(1972), 1069A.

Bass, Joel E., and Montague, Earl J." Piaget-Based Sequence of Instruction in Science," Science Education, LVI, 4(1972), 503-512.

Bauman, Dan. "Fortap: A Fortran Test Analysis Package." Fredonia, New York: Teacher Education Research Center, State University College, 1973. (Mimeographed.)

Beard, Ruth M. Piaget's Developmental Psychology. New York: The New American Library, Inc., 1969.

Benson, K. S. "A Comparison of Two Methods of Teaching Fifth Grade Science," Dissertation Abstracts, XXX (1968), 1067A.

Berliner, David C. and Cahen, Leonard S. "Trait-Treatment Interaction and Learning," Review of Research in Education, ed. Kerlinger, Vol. I. Itasca, Illinois: Peacock Publisher, 1973.

Billeh, Victor Y. "Cultural Bias in the Attainment of Concepts of the Biological Cell by Elementary School Children," Journal of Research in Science Teaching, VII, 2(1970), 73-83.

Binter, Alfred R. and Dewar, John A. "Teacher Commitments in a Discovery Process." Science Education, LII, 1(1968), 103.

Bloom, Benjamin S. Taxonomy of Educational Objectives, Handbook I: Cognitive Domain. New York: David McKay Company, Inc., 1956.

Bracht, Glenn H. "Experimental Factors Related to Aptitude-Treatment Interactions," Review of Educational Research, XL, 5(1970), 627-645.

Breickenbaugh, Barry E. "A Study of the Effects of a Structure Curriculum in Piagetian Type Operations on the Cognitive Coping of Elementary Children," Dissertation Abstracts, XXXIII, 5(1972), 2159A.

Brown, T. J. "A Study of the Use of Pupil Experimentation and Reading in the Development and Retention of Selected Science Principles in the Fifth Grade," Dissertation Abstracts, XXIX (1968), 4176A.

Bruner, Jerome S. The Process of Education. Cambridge, Mass: Harvard University Press, 1960.

_____. "The Act of Discovery." Harvard Education Review, XXXI (1961), 21-32.

Bruner, Jerome S., Goodnow, Jacqueline J., and Austin, G. A. A Study of Thinking. New York: Wiley, 1956.

Burns, Richard W. and Ellis, Barbara M. "What Is Discovery Learning?" Science Education, LIV, 2(1970), 107.

Butts, David P. "The Degrees to Which Children Conceptualize from Science Experience," Journal of Research in Science Teaching, 1(1963), 135-143.

Carlson, J. S. "Effect of Instruction on the Concept of Conservation of Substance," Science Education, LI (1967), 138-145.

Carpenter, R. "A Reading Method and An Activity Method in Elementary Science Instruction," Science Education, XLVII, 3(1963), 256-258.

Carroll, J. B. "Words, Meanings and Concepts," Harvard Educational Review, XXXIV (1964), 178-202.

Castaneda, Alfred, McCandless, Boyd R., and Palermo, David S. "The Children's Form of the Manifest Anxiety Scale," Child Development, XXVII (September, 1956), 317-326.

Clark, D. Cecil. "Teaching Concept in the Classroom: A Set of Teaching Prescriptions Derived From Experimental Research," Journal of Educational Psychology Monograph, LXII, 3(1971), 253-278.

Clyde, Dean J. Multivariate Analysis of Variance on Large Computers. Miami: Clyde Computing Services, 1969.

Coulter, John. "The Effectiveness of Inductive Laboratory, Inductive Demonstration and Deductive Laboratory in Biology," Journal of Research in Science Teaching, IV, 3(1966), 185-186.

Craig, R. "Directed Versus Independent Discovery of Established Relation," Journal of Educational Psychology, XLVII, 4(1956), 223-234.

Crocker, Robert K. et al. "A Comparison of Structured and Unstructured Modes of Teaching Science Process Activities," Journal of Research in Science Teaching, XIII, 3(1976), 267-274.

Cronbach, L. J. and Gleser, G. C. Psychological Tests and Personal Decisions. Urbana, Illinois: University of Illinois Press, 1965.

Cronbach, L. J. and Snow, R. E. Individual Differences in Learning Ability as a Function of Instructional Variables. Washington, D.C.: U.S. Government Printing Office, 1969.

Davis, John C. "Time Conservation: A Comparison of Performance on Piagetian Tasks by Selected Students." Dissertation Abstracts, XXXIII, 3(1972), 1055A.

Deutsche, Jean M. The Development of Children's Concepts of Causal Relations. Minneapolis: University of Minnesota Press, 1937.

Dewey, John. Democracy and Education. New York: The MacMillan Company, 1916.

Dixon, W. J. (ed.). BMD: Biomedical Computer Programs. Berkeley: University of California Press, 1970.

Domino, George. "Differential Prediction of Academic Achievement in Conforming and Independent Settings," Journal of Educational Psychology, LIX (1968), 256-260.

_____. "Interactive Effects of Achievement Orientation and Teaching Style on Academic Achievement," Journal of Educational Psychology, LXII, 5(1971), 427-431.

Duckworth, Eleanor. "Piaget Rediscovered," Journal of Research in Science Teaching, II (1964), 172-176.

Dunn, Olive J. "Multiple Comparisons Among Means," American Statistical Association Journal, LVI (March, 1961), 52-64.

Eaton, Edward J. "The Relationship of Three Factors in Printed Materials to Student Achievement," Journal of Research in Science Teaching, IV, 1(1966), 28-36.

Edwards, Allen L. Experimental Design in Psychological Research. New York: Holt, Rinehart and Winston, Inc., 1972.

Egan, Dennis E. and Greeno, James G. "Acquiring Cognitive Structure by Discovery and Rule Learning," Journal of Educational Psychology, LXIV, 1(1973), 85-97.

Elkind, David. "Children's Discovery of the Conservation of Mass, Weight, and Volume: Piaget Replication Study II," Journal of Genetic Psychology, XCVIII (June, 1961), 219-227.

Esler, William K. "Putting It All Together--Inquiry, Process, Science Concepts, and the Textbook," Science Education, LVII, 1(1973), 19-23.

Field, T. W. and Copley, A. J. "Cognitive Style and Science Achievement," Journal of Research in Science Teaching, VI (1969), 2-10.

Flanders, N. A. Teacher Influence, Pupil Attitudes and Achievement. U.S. Office of Education Cooperative Research Monograph No. 12, 1965.

Flanders, N. A., Anderson, J. Paul, and Amidon, Edmund J. "Measuring Dependence Proneness in the Classroom," Educational and Psychological Measurement, XXI (1961), 575-587.

Fox, David J. The Research Process in Education. New York: Holt, Rinehart and Winston, Inc., 1969.

Friot, Faith E. The Relationship Between An Inquiry Teaching Approach and Intellectual Development. Doctoral Dissertation, The University of Oklahoma, 1970.

Fry, Edward. "A Readability Formula That Saves Time," Journal of Reading, XI (1968), 513-516, 575-578.

Gage, N. L. (Ed.) Handbook of Research on Teaching. Chicago: Rand McNally and Company, 1967.

Gagné, R. M. "Psychological Issues in Science--A Process Approach." The Psychological Basis of Science. The American Association for the Advancement of Science, Washington, D.C., 1965.

Gagné, Robert. "The Acquisition of Knowledge," Psychological Review, LXIX (1962), 355-365.

Gagné, Robert M. The Conditions of Learning. New York: Holt, Rinehart, and Winston, 1964.

_____. "Some New Views of Learning and Instruction," Phi Delta Kappan, L (1970), 468-472.

Garone, J. "Children's Scientific Concept Development," Science Education, XLIV (1960), 104-107.

Gaudry, E., and Spielberger, C. D. Anxiety and Educational Achievement. New York: John Wiley and Sons, 1971.

Grams, A. J. and Wentworth, Q. "Children's Anxiety as Compared with Parents' Reports and Teachers' Ratings of Achievement." Presented at the American Psychological Association, August, 1962, St. Louis, Missouri.

Guthrie, John T. "Expository Instruction vs. Discovery Method," Journal of Educational Psychology, LVIII (February, 1967), 45-49.

Harvey, O. J., Hunt, David E., and Schroder, Harold M. Conceptual Systems and Personality Organization. New York: John Wiley & Sons, Inc., 1961.

Haslerud, G. M. and Meyers, S. "Transfer Value of Given and Individually Derived Principles," Journal of Educational Psychology, XLIX, 6 (1958), 293-298.

Hays, William L. Statistics for Psychologists. New York: Holt, Rinehart, and Winston, Inc., 1963.

Helgeson, Stanley L. An Investigation into the Relationships Between Concepts of Force Attained and Maturity as Indicated by Grade Levels. Doctoral Dissertation, The University of Wisconsin, 1967.

_____. The Relationships Between Concepts of Force Attained and Maturity As Indicated by Grade Levels. Technical Report #43, Wisconsin R & D Center for Cognitive Learning, The University of Wisconsin, Madison, March, 1968.

Hendrix, Gertrude. "A New Clue to Transfer of Learning," Elementary School Journal, XLVII (1947), 197-208.

_____. "Prerequisite to Meaning," The Mathematics Teacher, XLIII (July, 1950), 334-339.

Henkel, E. Thomas. "Undergraduate Physics and Critical Thinking Ability," Journal of Research in Science Teaching, V, 1(1967), 89-94.

Howe, Ann C. "The Acquisition and Growth of the Concept of Conservation of Liquid," Journal of Research in Science Teaching, XI, 2(1974), 105-112.

Hunt, E. B. Concept Learning: An Information Processing Problem. New York: Wiley, 1962.

Hunt, Emil B. and Hovland, Carl I. "Order of Consideration of Different Types of Concepts," Journal of Experimental Psychology, LIX, 4 (1960), 220-226.

Hurd, Paul D. New Directions in Teaching Secondary School Science. Chicago: Rand McNally and Company, 1969.

Huttenlocker, J. "Effects of Manipulation of Attributes of Efficiency of Concept Formation," Psychological Reports, X (1962), 503-509.

Inhelder, Barbel and Piaget, Jean. The Growth of Logical Thinking from Childhood to Adolescence. New York: Basic Books, 1958.

Johnson, Orval and Bommarito. Tests and Measurements in Child Development: A Handbook. New York: Jassey-Bass, Inc., 1971.

Kaufman, Barry A. "Psychological Implications of Discovery Learning in Science," Science Education, LV, 1(1971), 73-83.

Kaufman, Betsy Baer. "A Contemporary Review of the Inquiry Method of Teaching and Learning: A Study of Current Definitions and Rationales of the Inquiry Method of Teaching and Learning--1960-1970." Dissertation Abstracts, XXXIII (1972), 223A.

Keislar, Evan R. "The Learning Process and the Teaching of Science," The Science Teacher, XXIX, 8(1962), 18-25.

Kennedy, John. An Intuitive Approach to the Design and Analysis of Educational Experiments. (Prepublication manuscript). Worthington, Ohio: Charles A. Jones Publishing Co., 1974.

Kersh, Bert Y. "The Adequacy of Meaning as an Explanation for Superiority of Learning by Independent Discovery," Journal of Educational Psychology, XLIX, 5(1958), 282-292.

Kindler, Leonard I. "The Relative Effectiveness of Narrative and Expository Forms of Written Presentation in Developing Selected Cognitive Abilities in Science Studies," Dissertation Abstracts, XXXIII, 10(1973), 5577A.

Kittel, J. "An Experimental Study of the Effect of External Direction during Learning on Transfer and Retention of Principles," Journal of Educational Psychology, XLVIII, 7(1957), 391-405.

Klausmeier, Herbert J. and Harris, Chester W. (Ed.) Analysis of Concept Learning. New York: Academic Press, 1966.

Kline, Arlyn A. "A Study of the Relationship between Self-Directed and Teacher-Directed Eighth Grade Students Involved in an Open-Ended Supplementary ESCP Laboratory Block," Journal of Research in Science Teaching, VIII (1971), 263-271.

Koran, Mary Lou. "Differential Response to Inductive and Deductive Instructional Procedures," Journal of Educational Psychology, LXII, 4 (1971), 300-307.

Kuhn, D. J. "Science Teaching, Concept Formation, Learning Theory," Science Education, LVI, 2 (1972), 189-196.

Levitt, Eugene E. The Psychology of Anxiety. Indianapolis: Bobbs-Merrill, 1967.

Lovell, K., Kellet, V., and Moorhouse, E. "The Growth of the Concept of Speed: A Comparative Study," Journal of Child Psychology and Psychiatry, III (1962), 101-110.

Lowell, K. and Slater, A. "The Growth of the Concept of Time: A Comparative Study," Journal of Child Psychology and Psychiatry, I (1960), 179-190.

Mancini, Dino. "An Investigation of the Relationships Between Self-Concept of Ability, Classroom Verbal Interaction, and Achievement of Seventh Grade Pupils in Biological Science in Two Suburban Schools," Dissertation Abstracts, XXXIII, 10(1973), 5577A-5578A.

MacBeth, Douglas R. "The Extent to Which Pupils Manipulate Materials and Attainment of Process Skills in Elementary School Science," Journal of Research in Science Teaching, XI, 1(1974), 45-51.

Mascola, R. "Performance in Conceptualizing: Relationship Between Conceptual Frameworks and Skills of Inquiry," Journal of Research in Science Teaching, VI (1969), 29-35.

Mason, Herbert L. "Concepts in Biology," Journal of Research in Science Teaching, II, 3(1964), 244-246.

Mayer, Victor J. Unpublished Evaluation Instruments in Science Education: A Handbook, Science Education Information Reports. Columbus, Ohio: ERIC Information Analysis Center, The Ohio State University, 1974.

McCandless, Boyd R. and Castaneda, Alfred. "Anxiety in Children, School Achievement and Intelligence," Child Development, XXVII (1956), 379-382.

McCandless, Boyd R. and Evans, Ellis D. Children and Youth: Psychosocial Development. Hinsdale, Illinois: The Dryden Press, 1973.

McConnell, T. R. "Discovery Versus Authoritarian Identification in the Learning of Children," University of Iowa Studies in Education, IX, 5(1934).

Melton, A. W. (Ed.) Categories of Human Learning. New York: Academic Press, 1964.

Mitzel, Harold E. "The Impending Instruction Revolution," Phi Delta Kappan, LI, 8(1970), 434-439.

Montessori, Maria. The Montessori Method. Cambridge, Mass.: Robert Bently, 1912.

Myron, J. and Karplus, Robert. "Discovery or Invention?" The Science Teacher, XXIX (September, 1962), 45-51.

Nay, M. A. "The Discovery Method of Teaching," The ATA Magazine, XLVIII (March-April, 1968), 20-23.

Nelson, Miles A. and Abraham, Eugene C. "Inquiry Skills Measure," Journal of Research in Science Teaching, X, 4(1973), 291-298.

Nie, Norman H. and others. Statistical Package for the Social Sciences. 2d ed. New York: McGraw-Hill, Inc., 1975.

Nuthall, Graham. "An Experimental Comparison of Alternative Strategies for Teaching Concepts," American Educational Research Journal, V, 4(1968), 561-584.

Okey, James R. and Gagné, Robert M. "Revision of a Science Topic Using Evidence of Performance on Subordinate Skills," Journal of Research in Science Teaching, VII, 4(1970), 321-325.

Palermo, David S. "Racial Comparisons and Additional Normative Data on the Children's Manifest Anxiety Scale," Child Development, XXX (1959), 53-57.

Pella, Milton O. "Concept Learning in Science," The Science Teacher, XXXIII, 9(1966), 31-34.

Pella, Milton O. and Carey, Russell L. "Levels of Maturity and Levels of Understanding for Selected Concepts of the Particle Nature of Matter," Journal of Research in Science Teaching, V, 3(1967-1968), 202-215.

Pella, Milton O. and Stauss, Nyles G. "The Relationship Between Concept Attainment and Level of Maturity," Journal of Research in Science Teaching, V, 4(1967-1968), 299-310.

Pella, Milton O. and Voelker, Alan M. "Teaching the Concepts of Physical and Chemical Change to Elementary School Children," Journal of Research in Science Teaching, V, 4(1967-1968), 311-323.

Piaget, Jean. The Psychology of Intelligence. New York: Harcourt, Brace, and World, 1950.

_____. "Cognitive Development in Children: Piaget Development and Learning." Journal of Research in Science Teaching, II (1964), 176-187.

_____. The Child's Conception of Movement and Speed. New York: Basic Books, 1970.

Pollach, Samuel. "Individual Differences in the Development of Certain Science Concepts," Dissertation Abstracts, XXIV (1963), 146.

Rainey, Robert G. "The Effects of Directed Versus Non-Directed Laboratory Work on High School Chemistry Achievement," Dissertation Abstracts, XXIV (1962), 146-147.

_____. "The Effects of Directed Versus Non-Directed Laboratory Work on High School Chemistry Achievement," Journal of Research in Science Teaching, III (December, 1965), 293-299.

Raun, Chester E. and Butts, David P. "The Relationship Between the Strategies of Inquiry in Science and Student Cognitive and Affective Behavioral Change," Journal of Research in Science Teaching, V, 3(1967-1968), 261-268.

Raven, Ronald J. "The Development of the Concept of Momentum in Primary School Children," Journal of Research in Science Teaching, V, 3 (1967-1968), 216-223.

_____. "The Development of the Concept of Acceleration in Elementary School Children," Journal of Research in Science Teaching, IX, 3 (1972), 201-206.

Ray, W. "Pupil Discovery Versus Direct Instruction," Journal of Experimental Education, XXIX, 3 (March, 1961), 271-280.

Riley, Joseph W. "The Development and Use of a Group Process Test for Selected Processes of the Science Curriculum Improvement Study." Unpublished Doctoral Dissertation, Michigan State University, 1972.

Rosenblith, J. F. and Allinsmith, A. W. (Eds.) The Causes of Behavior: Readings in Child Development and Educational Psychology. Boston: Allyn and Bacon, 1962.

Rutherford, James F. "The Roles of Inquiry in Science Teaching," Journal of Research in Science Teaching, II, 2(1964), 80-84.

Salomon, Gauriel. "Heuristic Models for the Generation of Aptitude-Treatment Interaction Hypotheses," Review of Educational Research, XLII, 3(1971), 327-343.

Schefler, William C. "A Comparison Between Inductive and Illustrative Laboratories in College Biology," Journal of Research in Science Teaching, III, 3(1965), 218-223.

Scott, Norval C. "Science Concept Achievement and Cognitive Functions," Journal of Research in Science Teaching, II, 1(1964), 7-16.

_____. "The Strategy of Inquiry and Styles of Categorization," Journal of Research in Science Teaching, IV, 3(1966), 143-153.

_____. "Cognitive Style and Inquiry Strategy: A Five Year Study," Journal of Research in Science Education, X, 4(1973), 323-330.

Shulman, L. S. "Reconstruction of Educational Research," Review of Educational Research, XL, 3(1970), 371-397.

Shulman, L. S. and Keislar, E. R. (Eds.) Learning by Discovery: A Critical Appraisal, Chicago: Rand McNally and Company, 1966.

Siegel, Betsy Davidson and Raven, Ronald. "The Effect of Manipulation on the Acquisition of the Compensatory Concepts of Speed, Force and Work," Journal of Research in Science Teaching, VIII, 4(1971), 373-378.

Smedslund, Jan. "Concrete Reasoning: A Study of Intellectual Development," Monog. Society for Research in Child Development, XXIX, (1964), 93.

Spielberger, C. D. and Sarason, I. G. (Eds.) Stress and Anxiety, Volume 1. Washington: Hemisphere/Wiley, 1975.

Spielberger, Charles D. Anxiety: Current Trends in Theory and Research, Volume 1. New York: Academic Press, Inc., 1972.

Stanley, Julian C. and Hopkins, Kenneth D. Educational and Psychological Measurement and Evaluation. Englewood Cliffs, N. J.: Prentice-Hall, 1972.

Strahler, Violent R. "Relationship of Eight Predictive Factors to Science in Ninth-Grade Science and Mathematics," Dissertation Abstracts, XXXIII, 9(1973), 4970A.

Strike, Kenneth A. "The Logic of Learning by Discovery," Review of Educational Research, XLV (1975), 461-483.

Suchman, J. "Inquiry Training in the Elementary School," The Science Teacher, XXVII (1960), 42-43.

Tallmadge, G. K. and Shearer, J. W. "Interactive Relationships Among Learner Characteristics, Types of Learning, Instructional Methods, and Subject Matter Variables," Journal of Educational Psychology, LXII (1971), 31-38.

Tanner, Thomas R. "Expository-Deductive Versus Discovery-Inductive Programming of Physical Science Principles," Journal of Research in Science Teaching, VI (1969), 136-142.

Tatsuoka, Maurice M. Multivariate Methods, New York: John Wiley and Sons, 1971.

Taylor, Alton L. "The Influence of Teacher Attitudes and Individual Differences on Pupil Achievement with Programmed Science Materials," Journal of Research in Science Teaching, IV, 1(1969), 38-39.

Thomas, Barbara and Snider, Bill. "The Effects of Instructional Methods Upon the Acquisition of Inquiry Skills," Journal of Research in Science Teaching, VI, 4(1969), 377-386.

Tuckman, Bruce W. "Study of Interactive Effects of Teaching Style and Personality," American Psychological Association Proceeding, IV (1969), 637-638.

Voelker, Alan M. The Relative Effectiveness of Two Methods of Instruction in Teaching the Classificational Concepts of Physical and Chemical Change to Elementary School Children, Technical Report #39. Wisconsin R & D Center for Cognitive Learning, The University of Wisconsin, Madison, February, 1968.

_____. Science Paper 11--Research on Concept Learning: An Analysis, Science Education Information Reports, Columbus: The Ohio State University, ERIC Center for Science, Mathematics, and Environmental Education, March, 1973.

Welch, L. and Long, L. "The Higher Structural Phases of Concept Formation in Children," Journal of Psychology, IX (1940), 59-95.

White, Arthur L. and Smith, Douglas D. "A Study of the Effects of Varying Student Responsibility for Instructional Decisions in a CAI Course," Journal of Computer-Based Instruction, I, 1(1974), 13-21.

Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

Zingaro, Joseph S. and others. "A Statistical Comparison Between Inductive and Traditional Laboratories in College Physical Science," Journal of Research in Science Teaching, V, 3(1967-1968), 269-275.

APPENDIX A

PRETREATMENT INFORMATION AND INSTRUCTIONAL TASKS

PRETREATMENT INFORMATION INSTRUCTIONAL TASK 1

I. Description of Equipment

A. Meter stick (attached to a cigar box) --divided into units called centimeters. A centimeter is a unit of length or distance. An inch is also a unit of length or distance. Three Heights are labeled on the meterstick. The height is the distance from the label to the bottom of the sand.

B. Cigar box--contains sand

C. Sinker (identify)

D. Depth of Depression Measurer--can be used to measure a dent or depression made by the sinker hitting the sand. The depth of depression measurer is divided into units--Example of measurement (Press finger tip into sand and measure)

E. Related terms

1. Impact Force (Put on board) Drop book on table--The force with which the book hit the table is called impact force. Indicates how hard the book hit the table.

2. Depth of depression--is how far the sinker goes into the sand or how deep the sinker goes into the sand.

II. Calculations

A. Calculation of Average

1. Used to increase the correctness of your measurements.

2. Example on board.

Trial #1	Trial #2
2mm	4mm

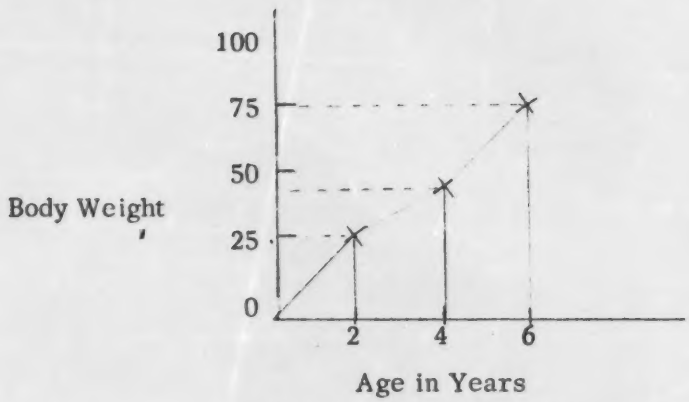
$$\text{average depression} = \frac{2\text{mm} + 4\text{mm}}{2} = 3\text{mm}$$

B. Use of graph

1. Use to show a relationship between two factors

2. Example

Age	Body Weight
Age #1 - 2 years	25 lbs.
Age #2 - 4 years	37 lbs.
Age #3 - 6 years	75 lbs.



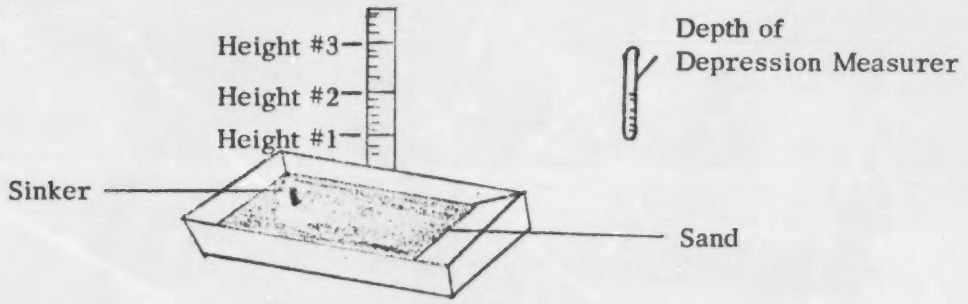
Read the worksheet carefully and follow the directions. Work by yourself--DO NOT TALK TO OTHER STUDENTS. You have 30 minutes to complete this activity. After you have completed all of your directions, you may experiment with the equipment. Be careful not to damage the equipment. If you have any questions, ask them now. Questions will not be answered during the activity.

INSTRUCTIONAL TASK #1

Name _____ Date _____ I.D.# _____

I. Today we want to think about how hard a sinker hits sand when it is dropped from different heights.

II. Study the drawing below. This drawing matches the arrangement of the equipment in this activity.



III. The variable being tested or changed in this experiment is the height from which the sinker is dropped into the sand. Height #3 is the greatest distance from the sand. Height #1 is the closest to the surface of the sand. You should also be interested in the depth of the depression in the sand. The depressions or dents are caused by the sinker hitting the sand. The depth of the depressions in the sand indicates how hard the sinker hits the sand or the sinker's impact force. The size of the sinker is always the same or constant. The size of the sinker is a variable held constant.

IV. Measurement Instructions:

A. The distance from each height to the bottom of the sand is labeled on the meterstick. Record each given distance in the space provided.

Distance from the bottom of the sand to Height #1 _____cm
Distance from the bottom of the sand to Height #2 _____cm
Distance from the bottom of the sand to Height #3 _____cm

B.--Height #1--Drop the sinker into the sand from Height #1. Use the procedure that we talked about to figure out the depth of depression. Record the depth of the depression in Table I under Trial #1. Repeat this procedure and record the depth of depression under Trial #2 in the table.

B.--Height #2--Drop the sinker from Height #2. Record the depth of depression in Table I under Trial #1. Repeat this procedure and record the depth of depression under Trial #2 in the table.

B.--Height #3--Drop the sinker into the sand from Height #3. Record the depth of depression in Table I under Trial #1. Repeat this procedure and record the depth of depression under Trial #2 in the table.

TABLE I

	Depth of Depression Trial #1	Trial #2
Height #1	_____ mm	_____ mm
Height #2	_____ mm	_____ mm
Height #3	_____ mm	_____ mm

V. Data Analysis Instructions:

A. You can use arithmetic to figure out the average depression made by the sinker hitting the sand. Study the formula given below. Use the depths of depression recorded in Table I to complete the following problems.

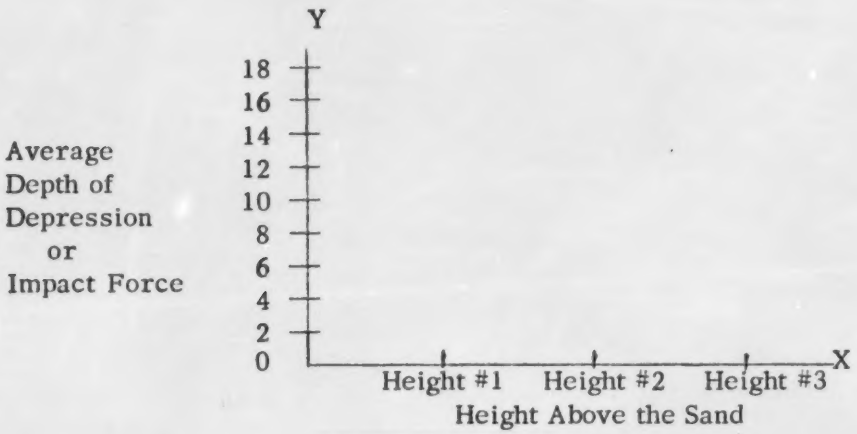
$$\text{Average depression per height} = \frac{\text{depression trial \#1 + \#2}}{\text{number of trials}}$$

1. Average depression Height #1 = $\frac{___\text{mm} + ___\text{mm}}{___\text{trials}} = ___\text{mm}$

2. Average depression Height #2 = $\frac{___\text{mm} + ___\text{mm}}{___\text{trials}} = ___\text{mm}$

3. Average depression Height #3 = $\frac{___\text{mm} + ___\text{mm}}{___\text{trials}} = ___\text{mm}$

B. You can use a graph to study the relationship between height and impact force. Use the average depression for each height to complete the graph.



VI. Written Questions: Review your data and circle the letter of the best answer.

1. If you had dropped the sinker from a height greater than Height #3, the sinker would hit the sand harder (more impact force) than it did when you dropped it from
   a) Height #1 b) Height #2 c) Height #3 d) all of the above

2. If you had dropped the sinker from a height less than Height #1, the sinker would hit the sand harder (more impact force) than it did when you dropped it from
   a) Height #1 b) Height #2 c) Height #3 d) none of the above

Check your answers:
1. The correct answer for question #1 is d.
2. The correct answer for question #2 is d.

If you missed one or both of the questions, review your data.

PRETREATMENT INFORMATION INSTRUCTIONAL TASK #2

I. Description of Equipment

A. Cart attached to a cup of sand by a string. The string passes over a pulley attached to a ring stand. The cup of sand provides a constant (always the same) pulling force. A rubber band is placed on the ramp at Point A. You can stop the cart from moving up the ramp by hooking the rubber band over the paper clip on the back of the cart.

B. Three weights--approximately equal in size. Weight #1 is already on the cart. (Show how weight can be attached to the cart - Example of weight--body weight).

C. The distance that the cart will move is from Point B to Point C (Labeled on the ramp).

D. Using the meterstick--meterstick is divided into 100 units called centimeters. A centimeter is a unit of distance (smaller than an inch)--Example: measure 105 cm distance marked on table with chalk.

E. Time measurement--Release the cart--immediately begin counting--(1001, 1002, 1003, 1004, etc.) until the cart stops at the top of the ramp or at Point C.--Example: without weight #1 attached--about 3 seconds. Note that 1003 = 3 seconds.

F. Related Terms

1. Speed (Put on board) is a measure of how fast or how quickly an object moves between two points. A car going (from home to school) at 20 miles/hour will move 20 miles in 1 hour.

2. Time or Number of Seconds--The faster a car is moving the less time is needed to get between two points. Example: If car (in #1 above) was moving at 40 miles/hour, it would take 1/2 hour to get to the school from your home.

II. Calculations

A. Calculation of Average

1. Used to increase the correctness of your measurement

2. Example on Board

Trial #1	Trial #2
2 seconds	4 seconds

$$\text{average time} = \frac{2 \text{ seconds} + 4 \text{ seconds}}{2 \text{ (Trials)}} = 3 \text{ seconds}$$

B. Calculation of Speed

1. Used to figure out how fast an object is moving

2. You divide the distance that the object moves by the average time needed

Example I: $\frac{\text{distance between two points}}{\text{average time}}$

$$= \frac{30 \text{ cm}}{3 \text{ seconds}} = 10\text{cm/second}$$

Example II: $\frac{\text{distance between two points}}{\text{average time}}$

$$= \frac{30 \text{ cm}}{.5 \text{ seconds}} = 6\text{cm/second}$$

The object in Example I moved faster than the object in Example II.

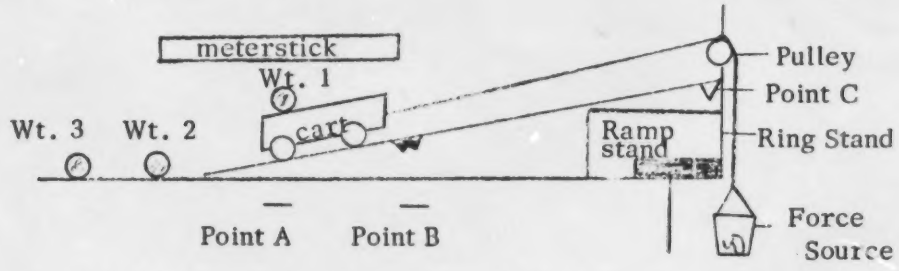
Read the worksheet carefully and follow the directions. Work by yourself--DO NOT TALK TO OTHER STUDENTS. You have 30 minutes to complete this activity. After you have completed all of your directions, you may experiment with the equipment. Be careful not to damage the equipment. If you have any questions, ask them now. Questions will not be answered during the activity. A short test will follow the activity.

INSTRUCTIONAL TASK #2

Name _____ Date _____ I.D.#_____

I. Today we want to think about how fast the cart moves up the ramp with different objects on it.

II. Study the drawing below. The drawing matches the arrangement of the equipment in this activity.



III. The variable being tested or changed in this experiment is the amount of weight that the cart carries up the ramp. When Weight #2 is placed on the cart with Weight #1, the amount of weight being carried by the cart is increased. The amount of weight is increased even more when Weight #3 is placed on the cart with Weight #1 and Weight #2. You should also be interested in the time (number of seconds) that it takes for the cart to move up the ramp. The time needed for the cart to move up the ramp indicates the cart's speed. The force used to pull the cart up the ramp is always the same or constant. This pulling force is a variable held constant.

IV. Measurement Instructions:

A. Using your meterstick, measure the distance from Point B on the ramp to Point C on the ramp. Record your measurement in the space provided.

Distance B to C _____ cm

B.--Weight #1--Release the cart and figure out the time needed for the cart to move from Point B to Point C with Weight #1 riding on it. Use the "counting procedure" that we talked about to figure out the time in seconds. Record the time in Table I under Trial #1. Repeat this procedure and record the time under Trial #2 in the table.

B.--Weight #2--Place Weight #2 on the cart with Weight #1. Release the cart and figure out the time needed for the cart to move from Point B to Point C with Weight #1 and Weight #2 riding on it. Record the time in Table I under Trial #1. Repeat this procedure and record the time under Trial #2 in Table 1.

B.--Weight #3--Place Weight #3 on the cart with Weight #1 and Weight #2. Release the cart and figure out the time needed for the cart to move from Point B to Point C with Weight #1, Weight #2, and Weight #3 riding on it. Record the time in Table I under Trial #1. Repeat this procedure and record the time under Trial #2.

TABLE I

Number of Weights on the Cart	Time Trial #1	Time Trial #2
Weight #1	____seconds	____seconds
Weight #1 + Weight #2	____seconds	____seconds
Weight #1 + Weight #2 + Weight #3	____seconds	____seconds

V. Data Analysis Instructions:

A. You can use arithmetic to figure out the average time needed for the cart to move up the ramp. Study the formula given below. Use the times recorded in Table I to complete the following problems.

$$\text{Average time} = \frac{\text{time trial \#1} + \text{time trial \#2}}{\text{number of trials}}$$

1. Average time Weight #1 = $\frac{\text{____ sec.} + \text{____ sec.}}{\text{____ trials}}$ = ____sec.

2. Average time Weight #1 and #2 = $\frac{\text{____ sec.} + \text{____ sec.}}{\text{____ trials}}$ = ____sec.

3. Average time Weight #1, #2 and #3 = $\frac{\text{____ sec.} + \text{____ sec}}{\text{____ trials}}$ = ____sec.

B. You can use arithmetic to figure out the speed at which the cart traveled by dividing the distance from B to C by the average time. Use the average time figured out above. Study the formula and complete the following problems.

$$\text{Average speed} = \frac{\text{Distance B to C}}{\text{average time}}$$

1. Speed with Weight 1 = $\frac{\text{Distance } ___ \text{ cm}}{\text{average time } ___ \text{ sec.}} = \frac{___ \text{ cm}}{\text{seconds}}$

2. Speed with Weight 1 & 2 = $\frac{\text{Distance } ___ \text{ cm}}{\text{average time } ___ \text{ sec.}} = \frac{___ \text{ cm}}{\text{seconds}}$

3. Speed with Weight 1,2 & 3 = $\frac{\text{Distance } ___ \text{ cm}}{\text{average time } ___ \text{ sec.}} = \frac{___ \text{ cm}}{\text{seconds}}$

Note that the distance from Point B to Point C does not change.

VI. Written Questions. Review your data and circle the letter of the best response.

1. If a weight greater than the combined weights of Weight #1, #2, and #3 had been placed on the cart, the speed of the cart would have been
   a) the same as the speed of the cart would have been
   b) faster than the cart traveled with Weight #3 riding on it
   c) slower than the cart traveled with Weight #3 riding on it

2. If the cart was pulled up the ramp without additional weight on it, the cart's speed would be
   a) faster than the cart traveled with Weight #1 riding on it
   b) slower than the cart traveled with Weight #1 riding on it
   c) the same as the speed at which the cart traveled with Weight #1 riding on it

Check your answers:
1. The correct answer for question #1 is c.
2. The correct answer for question #2 is a.

If you missed one or both of the questions, review your data.

PRETREATMENT INFORMATION INSTRUCTIONAL TASK #3

I. Description of Equipment

A. Two boxes of equal size and mass attached by a rubber band. The rubber band provides a pulling force. Point A should be lined up with the line on the side of Box I. Point B should be lined up with the line on the side of Box II. Two objects are labeled Mass I and Mass II.

B. Ruler--used to figure out the distance that Box I moves in inches. The distance moved is called motion. Example: 2 3/4 inches round to 3 inches--2 1/4 inches round to 2 inches.

C. Motion or Distance Measure--Pull the front edge of Box I even with Point A. Pull the front edge of Box II even with Point B. Release Box I and Box II at the same instant. Repeat--but do not release the boxes. Slide toward each other--Measure (ruler) from Point A to the front edge of Box I.

D. Related Terms

1. Mass (Put on board)--the amount of matter in an object. Similar to weight. Mass X gravity equals weight.

2. Motion is the distance an object moves. If object I moves 4 inches and object II moves 6 inches, then object II has more motion. The farther an object moves the more motion it has.

II. Calculations

A. Calculation of average

1. Used to increase the correctness of your measurements

2. Example on Board

Trial #1	Trial #2
6 inches	5 inches

$$\text{average distance} = \frac{6 \text{ inches} + 5 \text{ inches}}{2 \text{ (trials)}} = \frac{11}{2} = 5\ 1/2 \text{ inches}$$

B. Use of a pie graph

1. Used to show a relationship between two factors

2. Example: 5 1/2 (from #1)

If another object moved 3 inches

I

II

5 1/2

Object I moved more than Object II.

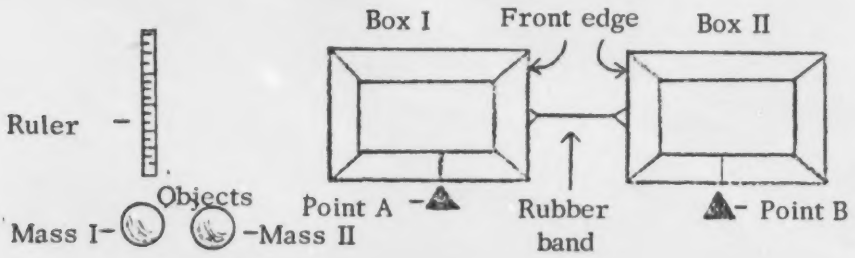
Read the worksheet carefully and follow the directions. Work by yourself--DO NOT TALK TO OTHER STUDENTS. You have 30 minutes to complete this activity. After you have completed all of your directions, you may experiment with the equipment. Be careful not to damage the equipment. If you have any questions ask them now. Questions will not be answered during the activity. A short test will follow the activity.

INSTRUCTIONAL TASK #3

Name _____ Date _____ I.D.# _____

I. Today we want to think about how far two boxes move if objects (masses) are placed in one of the boxes.

II. Study the drawing below. This drawing matches the arrangement of equipment in this activity.



III. The variable being tested or changed in this experiment is the amount of mass in Box I. When Object I is placed in Box I, the amount of mass being pulled by the rubber band is increased. The amount of mass is increased even more when Object II is placed in the box with Object I. You should also be interested in the distance that the rubber band pulls Box I. The distance that Box I moves is called motion. The size of the pulling force of the rubber band is always the same or constant. Pulling force is a variable held constant.

IV. Measurement Instructions:

A. Using your ruler, measure the distance from Point A to Point B. Record your measurement in the space provided.

Distance from Point A to Point B = _____ inches

B.--Box I--Pull the two boxes apart so that the rubber band stretches. The front edge of Box I should be at Point A. The front edge of Box II should be at Point B. Let both boxes go at exactly the same instant. Use the procedure that we talked about to figure out the distance that Box I moved. Record the distance that Box I moved in Table I under Trial #1. Repeat this procedure and record the distance measurement under Trial #2 in the table.

B.--Box I + Mass I--Place Mass I in Box I. Pull the two boxes apart so that the rubber band stretches. The front edge of Box I should be at Point A. The front edge of Box II should be at Point B. Let the boxes go at exactly the same instant. Record the distance that Box I moved in Table I under Trial #1. Repeat this procedure and record the distance measurement under Trial #2 in the table.

B.--Box 1 + Mass I + Mass II--Place Mass II in Box I with Mass I. Pull the two boxes apart so that the rubber band stretches. The front edge of Box I should be at Point A. The front edge of Box II should be at Point B. Let the boxes go at exactly the same instant. Record the distance that Box I moved in Table I under Trial #1. Repeat this procedure and record the distance that Box I moved under Trial #2 in the table.

TABLE I

	Trial #1	Trial #2
Box I	_____ inches	_____ inches
Box I + Mass I	_____ inches	_____ inches
Box I + Mass I + Mass II	_____ inches	_____ inches

V. Data Analysis Instructions:

A. You can use arithmetic to figure out the average distance that Box I moved. Study the formula given below. Use the distance in Table I to complete the following problems.

$$\text{Average distance} = \frac{\text{Distance Trial \#1} + \text{Distance Trial \#2}}{\text{Number of Trials}}$$

		Average Distance Moved
Box I only	= $\frac{\text{____ inches} + \text{____ inches}}{\text{____ trials}}$ =	____ inches
Box I + Mass I	= $\frac{\text{____ inches} + \text{____ inches}}{\text{____ trials}}$ =	____ inches
Box I + Masses I & II	= $\frac{\text{____ inches} + \text{____ inches}}{\text{____ trials}}$ =	____ inches

B You can use "pie graphs" to study the relationship between mass and motion. Example: If Box I had moved an average of 4 inches, your pie would look like this:

Color in one piece of the pie for each inch that Box I moved.

Use the average distances that you just figured out to complete the three pie graphs.

Box I only

Box I + Mass I

Box I + Masses I & II

VI. Written Questions: Review your data and circle the letter of the best answer.

1. If a third mass was added to Mass I and Mass II in Box I, then Box I would move
   a) farther than it did with Mass I
   b) farther than it did with Mass I and Mass II
   c) a shorter distance than with Mass I

2. If you added Mass II to Box II and Mass I to Box I, then Box I would have moved
   a) farther than Box II
   b) a shorter distance than Box II
   c) the same distance as Box II

Check your answers:
1. The correct answer to question #1 is c.
2. The correct answer to question #2 is c.
If you missed one or both of the questions, review your data.

PRETREATMENT INFORMATION INSTRUCTIONAL TASK #4

I. Description of Equipment

A. Cart being held in place (Note--back wheel pointer) by a string on a ramp. A wooden block is placed between the bottom of the ramp and Point A. A meter stick is placed at the bottom of the ramp. A meter stick is divided into 100 units called centimeters. A centimeter is a unit of distance (smaller than an inch) --Example: measure 106 centimeters marked on table with chalk.

B. Three masses--approximately equal in size. Mass I is already on the cart. Show how mass can be attached to the cart.

C. Distance block moves from Point A--Remove Mass I from the cart and allow the cart to hit the wooden block. Use the meter stick to measure the distance moved (from Point A to the edge of the block nearest to the ramp).

D. Related Terms

1. Momentum (Put on board) --the size/amount or quantity of the force of motion/movement. The distance that a nonmoving object is knocked by a moving object is a measure of the moving object's momentum (e.g., Volkswagen striking a trash can).

2. Mass (Put on board)--the amount of matter in an object. Similar to weight. Mass X gravity equals weight.

II. Calculations

A. Calculation of average

1. Used to increase the correctness of your measurement

2. Example on board

Trial #1	Trial #2
25 cm	35 cm

$$\text{Average distance knocked} = \frac{25 \text{ centimeters} + 35 \text{ centimeters}}{2 \text{ (trials)}}$$

$$= \frac{60}{2} = 30 \text{ centimeters}$$

B. Multiplication by 5

Example:

5 x 1000 = 5,000

5 x 100 = 500

5 x 10 = 50

The speed of the cart is always 5cm/second

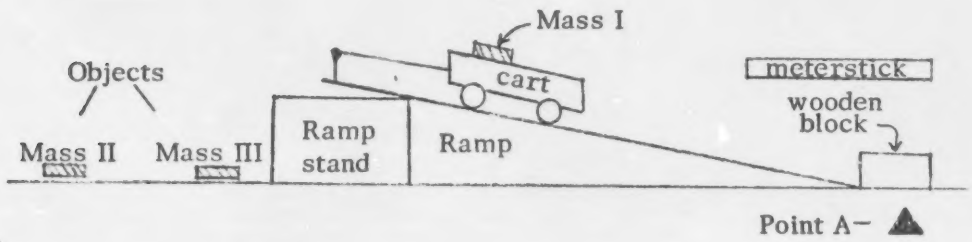
Read the worksheet carefully and follow the directions. Work by yourself--DO NOT TALK TO OTHER STUDENTS. You have 30 minutes to complete this activity. After you have completed all of your directions, you may experiment with the equipment. Be careful not to damage the equipment: If you have any questions, ask them now. Questions will not be answered during the activity. A short test will follow the activity.

INSTRUCTIONAL TASK #4

Name _____ Date _____ I.D.# _____

I. Today we want to think about how far a cart will knock a wooden block with different objects placed on the cart.

II. Study the drawing below. This drawing matches the arrangement of equipment in this activity.



III. The variable being tested or changed in this experiment is the amount of mass placed on the cart. When Object II is placed on the cart with Object I, the amount of mass being carried by the cart is increased. The amount of mass is increased even more when Object III is placed on the cart with Object I and Object II. You should also be interested in the distance that the cart knocks the wooden block. The distance that the wooden block is knocked is a measure of the cart's momentum. The size of the wooden block is always the same or constant. The size of the wooden block is a variable held constant.

IV. Measurement Instructions:

A. The mass of Object I is 100 grams. The mass of Object II is 100 grams. The mass of Object III is 100 grams. Using this information, complete the two addition problems in Table I.

TABLE I

Mass Being Carried by the Cart	Distance Block Moves From Point A Trial #1	Trial #2
Mass I = 100 grams	____cm	____cm
Mass I + Mass II = ____grams	____cm	____cm
Mass I + Mass II + Mass III = ____grams	____cm	____cm

B.--Cart + Mass I--Place Mass I in the cart. Allow the cart to roll down the ramp and hit the wooden block. Use the procedure that we talked about to figure out the distance that the wooden block was knocked. Record the distance that the wooden block was knocked in Table I under Trial #1. Slide the wooden block back to the bottom of the ramp. Repeat this procedure and record the distance measurement under Trial #2 in the table.

B.--Cart + Mass I + Mass II--Place Mass I and Mass II in the cart. Allow the cart to roll down the ramp and hit the wooden block. Record the distance that the wooden block was knocked in Table I under Trial #1. Slide the wooden block back to the bottom of the ramp. Repeat this procedure and record the distance measurement under Trial #2 in the table.

B.--Cart + Mass I + Mass II + Mass III--Place Mass I, Mass II, and Mass III in the cart. Allow the cart to roll down the ramp and hit the wooden block. Record the distance that the wooden block was knocked in Table I under Trial #1. Slide the wooden block back to the bottom of the ramp. Repeat this procedure and record the distance measurement under Trial #2 in the table.

V. Data Analysis Instructions:

A. You can use arithmetic to figure out the average distance that the wooden block was knocked. Study the formula given below. Use the distance measurements in Table I to complete the following problems.

$$\text{Average distance per mass} = \frac{\text{Distance Trial \#1} + \text{Distance Trial \#2}}{\text{Total Number of Trials}}$$

(1) Average distance Mass I = $\frac{\text{___ cm} + \text{___ cm}}{\text{___ trials}}$ = ___ cm

(2) Average distance Masses I & II = $\frac{\text{___ cm} + \text{___ cm}}{\text{___ trials}}$ = ___ cm

(3) Average distance Masses I, II & III = $\frac{\text{___ cm} + \text{___ cm}}{\text{___ trials}}$ = ___ cm

The average distance that the wooden block was knocked is a measure of the cart's momentum.

B. You can use arithmetic to figure out the momentum (the force of motion) of the cart when it hit the wooden block. Momentum is a measure of the force of motion. The speed of the cart was always 5 cm/second. Study the formula given below. Use the Mass (number of grams) recorded in Table I to complete the three problems. Each object has a mass of 100 grams.

Momentum = Total Mass of Objects X Speed of the Cart

(1) Mass I Momentum = 100 grams X 5cm/sec = ____

(2) Mass I + Mass II Momentum = _____grams X 5cm/sec = ____

(3) Mass I + Mass II Mass III Momentum = ____grams X5cm/sec

= ____

VI. Written Questions: Review your data and circle the letter of the best answer.

1. If a fourth object were placed in the cart with Object I, Object II, and Object III, the distance that the wooden block would move would be
   a) less than with Object I in the cart
   b) less than with Object I and Object II in the cart
   c) more than with Object I, Object II, and Object III in the cart

2. If you allowed the cart to roll down the ramp and hit the wooden block without adding any objects to the cart, the distance that the wooden block would move would be
   a) more than with Object I in the cart
   b) less than with Object I in the cart
   c) more than with Object I and Object II in the cart

Check your answers:
1. The correct answer to question #1 is c.
2. The correct answer to question #2 is b.

If you missed one or both of the questions, review your data.

PRETREATMENT INFORMATION INSTRUCTIONAL TASK #5

I. Description of Equipment

A. A wooden block is attached to a force-measurer by a string. The front of the wooden block should be at Point A. The force-measurer scale is divided into units called Newtons. A newton is a unit of force like an inch is a unit of length or distance. Example: Pick up wooden block using the force-measurer--allow students to see the reading.

B. Three Weights--approximately equal in size. Weight I is already on the wooden block. Show how weights can be attached to the wooden block.

C. Force-measurer reading--Slide block from Point A to Point B without Weight #1 on waxpaper surface. Note the reading. The reading is an indicator of the force of friction.

D. Related Terms

1. Force of friction (Put on board)--The force that must be overcome for an object to move from Point A to Point B. Example: Place finger tips of left hand on base of palm of right hand--slowly slide left hand forward over right hand. The unit of force is Newton.

2. The force-measurer tells you the force of friction. Five Newtons of pulling force is greater than three Newtons of pulling force. You must pull harder to get a force-measurer reading of five Newtons.

II. Calculations

A. Calculation of average

1. Used to increase the correctness of your measurements

2. Example on board

Trial #1	Trial #2
5 Newtons	10 Newtons

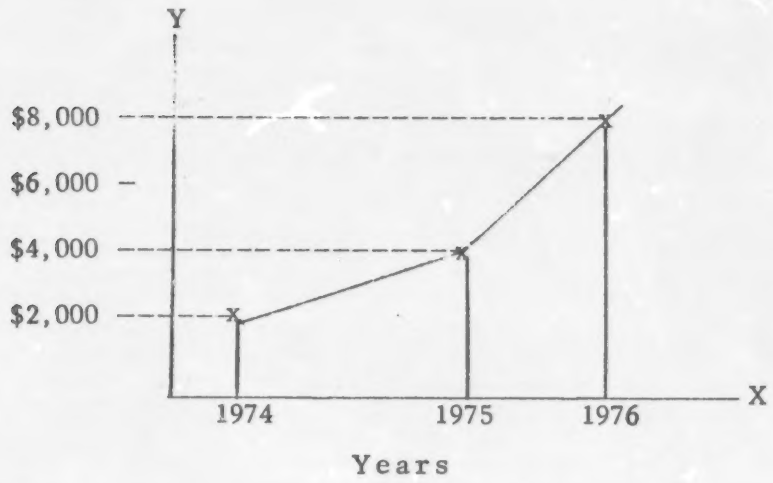
$$\text{Average Force of Friction} = \frac{5 \text{ newtons} + 10 \text{ newtons}}{2 \text{ (trials)}} = 7\ 1/2 \text{newtons}$$

B. Use of graph

1. Used to show a relationship between two factors

2. Example:

Years	Salary
1974	$2,000
1975	$4.000
1976	$8,000



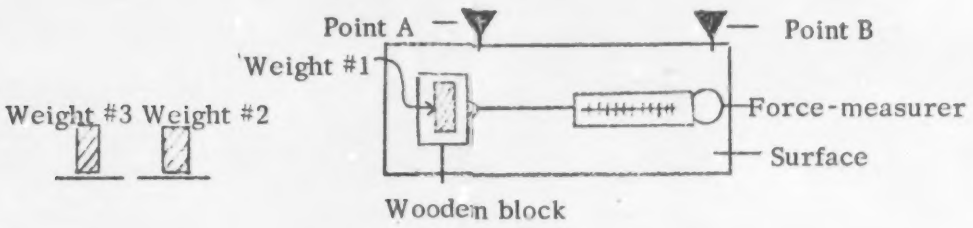
Read the worksheet carefully and follow the directions. Work by yourself--DO NOT TALK TO OTHER STUDENTS. You have 30 minutes to complete this activity. After you have completed all of your directions, you may experiment with the equipment. Be careful not to damage the equipment. If you have any questions, ask them now. Questions will not be answered during the activity. A short test will follow the activity.

INSTRUCTIONAL TASK #5

Name _____ Date _____ I.D.# _____

I. Today we want to think about the amount of force needed to pull a wooden block plus different weights across a surface.

II. Study the drawing below. This drawing matches the arrangement of equipment in this activity.



III. The variable being tested or changed in this experiment is the amount of weight that you place on the wooden block. As you add more weights to the wooden block, the amount of weight on the block increases. The amount ofweight on the wooden block is greatest with all three weights on it. You should also be interested in the force-measurer reading that you get when you pull the wooden block from Point A to Point B. The force-measurer indicates the force of friction. The force of friction must be overcome before the wooden block will move. The surface that the wooden block is resting on is always the same or constant. The surface is a variable held constant.

IV. Measurement Instructions:

A. Use your force-measurer to weigh the wooden block. Record the weight of the wooden block in the space provided.

Weight of wooden block _____ Newtons

B.--Block + Weight #1--Pull the wooden block plus Weight #1 from Point A to Point B. Use the procedure that we talked about to figure out the force of friction. Record the force of friction in Table I under Trial #1. Repeat this procedure and record the force of friction reading under Trial #2 in the table.

B.--Block + Weights #1 & 2--Pull the wooden block plus Weight #1 and Weight #2 from Point A to Point B. Record the force of friction reading in Table I under Trial #1. Repeat this procedure and record the force of friction reading under Trial #2 in the table.

B.--Block + Weights #1, 2 & 3--Pull the wooden block plus Weight #1, Weight #2, and Weight #3 from Point A to Point B. Record the force of friction reading in Table I under Trial #1. Repeat this procedure and record the force of friction reading under Trial #2 in the table.

TABLE I

	Force-Measurer Reading Trial #1	Trial #2
Block + Weight #1	___ Newtons	___ Newtons
Block + Weights #1 & 2	___ Newtons	___ Newtons
Bicok + Weights #1, 2 & 3	___ Newtons	___ Newtons

A. You can use arithmetic to figure out the average force of friction. Study the formula given below. Use the force-measurer reading recorded in Table I to complete the following problems.

$$\text{Average force of friction} = \frac{\text{Force Trial \#1} + \text{Force Trial \#2}}{\text{number of trials}}$$

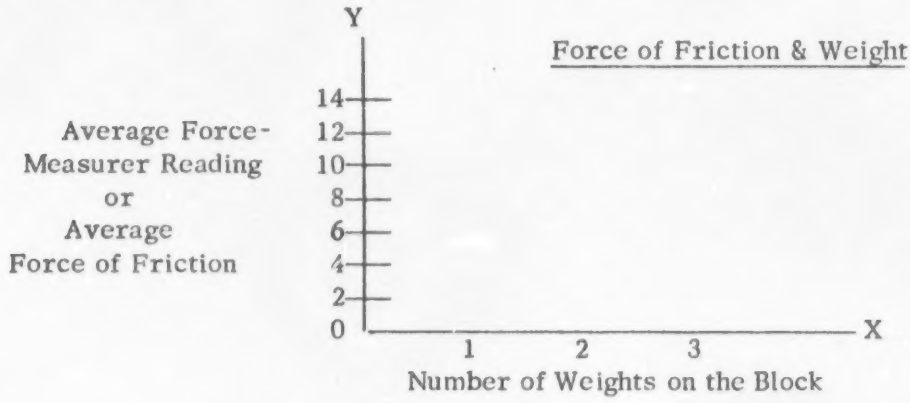
Average Force of Friction

(1) Block + Weight #1 = $\frac{\text{___ newtons} + \text{___ newtons}}{\text{___ trials}}$ = ___ newtons

(2) Block + Weights #1 & 2 = $\frac{\text{___ newtons} + \text{___ newtons}}{\text{___ trials}}$ = ___ newtons

(3) Block + Weights #1, 2 & 3 = $\frac{\text{___ newtons} + \text{___ newtons}}{\text{___ trials}}$ = ___ newtons

B. You can use a graph to study the relationship between weight and force of friction. Use the average force of friction (above) for each weight to complete the graph.



VI. Written Questions: Review your data and circle the letter of the best answer.

1. If a fourth weight were added to the block with Weight #1, #2, and #3 and pulled across the surface, the Force-Measurer Reading would be
   a) less than with Weight #1
   b) more than with Weight #1
   c) the same as with Weight #1

2. If you pulled the wooden block across the surface without adding weight, the Force-Measurer Reading would be
   a) lower than with Weight #1
   b) lower than with Weight #2
   c) all of the above

Check your answers:
1. The correct answer to question #1 is b.
2. The correct answer to question #2 is c.

If you missed one or both of the questions, review your data.

APPENDIX B

CONCEPT COMPONENT PRETEST AND FIVE KNOWLEDGE LEVEL POSTTESTS

Name _____ I.D.# _____ Date _____

CONCEPT COMPONENT PRETEST

Match the phrase in List A with the term in List B.

List A	List B
____ 1. A measure of the rate of change of speed	A. Pulling force
____ 2. A measure of the amount of matter in an object	B. Force of friction
____ 3. A measure of the force of gravity on an object	C. Motion
____ 4. A measure of the quantity of the force of motion	D. Surface roughness
____ 5. A resistance to motion	E. Mass
____ 6. The action of changing position	F. Speed
____ 7. The upward force acting upon an object in a liquid	G. Weight
____ 8. A force causing an object to move in the direction of the force	H. Acceleration
____ 9. The force exerted when one object hits another object	I. Buoyant force
____10. The rate at which an object moves over a certain distance	J. Impact force
____11. Results from slight bumps in the exterior of an object	K. Momentum
	L. Work

POSTTEST INSTRUCTIONAL TASK #1

DIRECTIONS

Write your name, grade, the data and your teacher's name at the top of the Answer Sheet. Read each question carefully. Select the BEST answer. Circle the letter of your answer on the Answer Sheet. DO NOT write on the test. Be sure the number of the question matches the number on the Answer Sheet.

BE SURE TO ANSWER EACH QUESTION

1. You dropped the sinker into the sand from three different heights. From which height was the sinker's impact force the greatest?

   a. Height #1
   b. Height #2
   c. Height #3
   d. Impossible to say.

2. As the height that the sinker dropped increased, the depth of the depression in the sand

   a. increased.
   b. stayed the same.
   c. decreased.
   d. impossible to say.

3. How did height affect impact force?

   a. The greater the height, the lesser the impact force.
   b. The greater the height, the greater the impact force.
   c. The lesser the height, the greater the impact force.
   d. Both A and C are correct.

4. Which statement is true about the depth of depression made by the sinker hitting the sand?

   a. The farther that the sinker fell, the greater the depth of depression.
   b. The farther that the sinker fell, the smaller the depth of depression.
   c. The closer that the sinker was to the sand when you dropped it, the greater the depth of depression.
   d. The distance that the sinker fell did not influence the depth of depression.

5. The impact force of the sinker hitting the sand from Height #3 was greater than it was when you dropped the sinker from

   a. Height #1.
   b. Height #2.
   c. Both Height #1 and Height #2.
   d. None of the above is correct.

6. When the sinker hit the sand it made a dent. The dent in the sand was the deepest when the sinker was dropped from

   a. Height #1.
   b. Height #2.
   c. Height #3.
   d. All dents in the sand were equal.

7. The impact force of the sinker hitting the sand from Height #1 was greater than it was when you dropped the sinker from

   a. Height #2.
   b. Height #3.
   c. Both Height #2 and Height #3.
   d. Impossible to say.

8. The sinker hit the sand the hardest when you dropped the sinker from

   a. Height #1.
   b. Height #2.
   c. Height #3.
   d. Impossible to say.

9. As the height that the sinker dropped became greater, the impact force of the sinker hitting the sand

   a. became greater.
   b. stayed the same.
   c. became less.
   d. impossible to say.

10. You dropped the sinker into the sand from three different heights. From which height was the sinker's impact force the smallest?

a. Height #1.
b. Height #2.
c. Height #3.
d. Impossible to say.

POSTTEST INSTRUCTIONAL TASK #2

DIRECTIONS

Write your name, grade, the date, and your teacher's name at the top of the Answer Sheet. Read each question carefully. Select the BEST answer. Circle the letter of your answer on the Answer Sheet. DO NOT write on the test. Be sure the number of the question matches the number on the Answer Sheet.

BE SURE TO ANSWER EACH QUESTION

1. You allowed the cart to roll up the ramp with three different amounts of weight placed on it. With which amount of weight was the cart's speed smallest?

   a. Weight #1
   b. Weight #1 and Weight #2
   c. Weight #1, Weight #2, and Weight #3
   d. Impossible to say.

2. As the amount of weight placed on the cart became greater, the speed of the cart

   a. became greater.
   b. stayed the same.
   c. became less.
   d. impossible to say.

3. The cart moved up the ramp the fastest with

   a. Weight #1 placed on the cart.
   b. Weight #1 and Weight #2 placed on the cart.
   c. Weight #1, Weight #2, and Weight #3 on the cart.
   d. Impossible to say.

4. The speed of the cart moving up the ramp with Weight #1 riding on it was greater than the speed of the cart with

   a. Weight #1 and Weight #2 on the cart.
   b. Weight #1, Weight #2, and Weight #3 on the cart.
   c. Both a and b are correct.
   d. None of the above are correct.

5. When you released the cart, the cart moved up the ramp. The cart moved up the ramp most quickly when the cart carried

   a. Weight #1.
   b. Weight #1 and Weight #2.
   c. Weight #1, Weight #2, and Weight #3.
   d. The quickness of the cart moving up the ramp was always the same.

6. The speed of the cart moving up the ramp with Weight #1, Weight #2, and Weight #3 on it was greater than the speed of the cart with

   a. Weight #1 on the cart.
   b. Weight #1, Weight #2 on the cart.
   c. Both a and b are correct.
   d. None of the above are correct.

7. Which statement is true about the time or number of seconds needed for the cart to move up the ramp?

   a. The greater the amount of weight carried by the cart, the greater the time needed.
   b. The greater the amount of weight carried by the cart, the lesser the time needed.
   c. The smaller the amount of weight carried by the cart, the greater the time needed.
   d. The amount of weight carried by the cart did not influence the time needed for the cart to move up the ramp.

8. How did the amount of weight placed on the cart affect the cart's speed?

   a. The greater the amount of weight, the lesser the speed of the cart.
   b. The greater the amount of weight, the greater the speed of the cart.
   c. The lesser the amount of weight, the greater the speed of the cart.
   d. Both a and c are correct.

9. As the amount of weight placed on the cart increased, the amount of time (number of seconds) needed for the cart to move up the ramp

   a. increased.
   b. stayed the same.
   c. decreased.
   d. impossible to say.

10. You allowed the cart to roll up the ramp with three different amounts of weight placed on it. With which amount of weight was the cart's speed the greatest?

    a. Weight #1
    b. Weight #1 and Weight #2
    c. Weight #1, Weight #2, and Weight #3
    d. Impossible to say.

POSTTEST INSTRUCTIONAL TASK #3

DIRECTIONS

Write your name, grade, the data, and your teacher's name at the top of the Answer Sheet. Read each question carefully. Select the BEST answer. Circle the letter of your answer on the Answer Sheet. DO NOT write on the test. Be sure the number of the question matches the number on the Answer Sheet.

BE SURE TO ANSWER EACH QUESTION

1. You released Box I with three different amounts of mass. With which amount of mass was the motion of Box I the smallest?

   a. Box I only - without adding Mass I or Mass II
   b. Mass I added to Box I
   c. Mass I and Mass II added to Box I
   d. Impossible to say.

2. As the amount of mass placed in Box I became greater, the motion of Box I

   a. became greater.
   b. stayed the same.
   c. became less.
   d. impossible to say.

3. The rubber band pulled Box I the farthest with

   a. No additional Mass in Box I.
   b. Mass I placed in Box I.
   c. Mass I and Mass II placed in Box I.
   d. Impossible to say.

4. The motion of Box I without adding mass was greater than the motion of Box I with

   a. Mass I added to Box I.
   b. Mass I and Mass II added to Box I.
   c. Both a and b are correct.
   d. None of the above are correct.

5. When you released Box I, Box I moved toward Box II. Box I moved more inches when Box I carried

   a. No additional mass.
   b. Mass I.
   c. Mass I and Mass II.
   d. The distance that Box I moved was always the same.

6. The motion of Box I with Mass I and Mass II placed in it was greater than the motion of Box I with

   a. No additional mass.
   b. Mass I placed in Box I.
   c. Both a and b are correct.
   d. None of the above are correct.

7. Which statement is true about the distance that Box I moved when you released Box I from Point A?

   a. The greater the amount of mass placed in Box I, the greater the distance moved.
   b. The greater the amount of mass placed in Box I, the smaller the distance moved.
   c. The smaller the amount of mass placed in Box I, the smaller the distance moved.
   d. The amount of mass placed in Box I did not influence the distance that Box I moved from Point A.

8. How did the amount of mass placed in Box I affect the motion of Box I?

   a. The greater the amount of mass, the smaller the motion.
   b. The greater the amount of mass, the greater the motion.
   c. The smaller the amount of mass, the greater the motion.
   d. Both a and c are correct.

9. As the amount of mass placed in Box I increased, the distance that Box I moved

   a. increased.
   b. stayed the same.
   c. decreased.
   d. impossible to say.

10. You released Box I with three different amounts of mass. With which amount of mass was the motion of Box I the greatest?

a. Box I only - without adding Mass I or Mass II
b. Mass I added to Box I
c. Mass I and Mass II added to Box I
d. Impossible to say.

POSTTEST INSTRUCTIONAL TASK #4

DIRECTIONS

Write your name, grade, the date, and your teacher's name at the top of the Answer Sheet. Read each question carefully. Select the BEST answer. Circle the letter of your answer on the Answer Sheet. DO NOT write on the test. Be sure that the number of the question matches the number on the Answer Sheet.

BE SURE TO ANSWER EACH QUESTION

1. You allowed the cart to roll down the ramp with three different amounts of mass placed on the cart. With which amount of mass was the cart's momentum the greatest?

   a. Mass I
   b. Mass I and Mass II
   c. Mass I and Mass II and Mass III
   d. Impossible to say.

2. As the amount of mass carried by the cart increased, the distance that the wooden block was knocked

   a. increased.
   b. stayed the same.
   c. decreased.
   d. impossible to say.

3. How did the amount of mass placed on the cart affect the cart's momentum?

   a. The greater the amount of mass, the lesser the momentum.
   b. The greater the amount of mass, the greater the momentum.
   c. The lesser the amount of mass, the greater the momentum.
   d. Both a and c are correct.

4. Which statement is true about the distance that the wooden block was knocked when the cart hit it?

   a. The greater the amount of mass carried by the cart, the greater the distance knocked
   b. The greater the amount of mass carried by the cart, the smaller the distance knocked
   c. The smaller the amount of mass carried by the cart, the greater the distance knocked
   d. The amount of mass carried by the cart did not influence the distance that the wooden block was knocked

5. The momentum of the cart hitting the wooden block with Mass I, Mass II and Mass III riding on it was greater than the momentum of the cart with

   a. Mass I on the cart.
   b. Mass I and Mass II on the cart.
   c. Both a and b are correct.
   d. None of the above are correct.

6. When the cart hit the wooden block, the wooden block moved. The wooden block moved the farthest when the cart carried

   a. Mass I.
   b. Mass I and Mass II.
   c. Mass I, and Mass II, and Mass III.
   d. The distance that the block moved was always the same.

7. The momentum of the cart hitting the wooden block with Mass I riding on it was greater than the momentum of the cart with

   a. Mass I and Mass II on the cart.
   b. Mass I, Mass II, and Mass III on the cart.
   c. Both a and b are correct.
   d. None of the above are correct.

8. The cart hit the wooden block the hardest when it rolled down the ramp with

   a. Mass I riding on the cart.
   b. Mass I and Mass II riding on the cart.
   c. Mass I, Mass II, and Mass III riding on the cart.
   d. Impossible to say.

9. As the amount of mass carried by the cart became greater, the momentum of the cart hitting the wooden block

   a. became greater.
   b. stayed the same.
   c. became less.
   d. impossible to say.

10. You allowed the cart to roll down the ramp with three different amounts of mass placed on it. With which amount of mass was the cart's momentum the smallest?

   a. Mass I
   b. Mass I and Mass II
   c. Mass I and Mass II and Mass III
   d. Impossible to say.

POSTTEST INSTRUCTIONAL TASK #5

DIRECTIONS

Write your name, grade, the date, and your teacher's name at the top of the Answer Sheet. Read each question carefully. Select the BEST answer. Circle the letter of your answer on the Answer Sheet. DO NOT write on the test. Be sure that the number of the question matches the number on the Answer Sheet.

BE SURE TO ANSWER EACH QUESTION

1. You pulled the wooden block from Point A to Point B with three different amounts of weight placed on the wooden block. With which amount of weight was the force of friction the greatest?

   a. Weight #1
   b. Weight #1 and Weight #2
   c. Weight #1, Weight #2, and Weight #3
   d. Impossible to say.

2. As the amount of weight placed on the wooden block increased, the amount of the force-measurer reading

   a. increased.
   b. stayed the same.
   c. decreased.
   d. impossible to say.

3. How did the amount of weight placed on the wooden block affect the force of friction?

   a. The greater the amount of weight, the lesser the force of friction.
   b. The greater the amount of weight, the greater the force of friction.
   c. The lesser the amount of weight, the greater the force of friction.
   d. Both a and c are correct.

4. Which statement is true about the force-measurer reading when you pulled the wooden block from Point A to Point B?

   a. The greater the amount of weight placed on the wooden block, the greater the force-measurer reading.
   b. The greater the amount of weight placed on the wooden block, the smaller the force-measurer reading.
   c. The smaller the amount of weight placed on the wooden block, the greater the force-measurer reading.
   d. The amount of weight placed on the wooden block did not influence the force-measurer reading.

5. The force of friction of the wooden block with Weight #1, Weight #2 and Weight #3 placed on it was greater than the force of friction with

   a. Weight #1 on the wooden block.
   b. Weight #1 and Weight #2 on the wooden block.
   c. Both a and b are correct.
   d. None of the above are correct.

6. When you pulled the wooden block, the wooden block moved. You had to use more physical strength or muscle power to move the wooden block with

   a. Weight #1 placed on the wooden block.
   b. Weight #1 and Weight #2 placed on the wooden block.
   c. Weight #1, Weight #2, and Weight #3 placed on the block.
   d. The muscle power needed to pull the wooden block was always the same.

7. The force of friction of the wooden block with Weight #1 placed on it was greater than the force of friction with

   a. Weight #1 and Weight #2 placed on the wooden block.
   b. Weight #1, Weight #2, and Weight #3 placed on the wooden block.
   c. Both a and b are correct.
   d. None of the above are correct.

8. In order to move the wooden block from Point A to Point B, you had to pull the hardest when

   a. Weight #1 was placed on the wooden block.
   b. Weight #1 and Weight #2 was placed on the wooden block.
   c. Weight #1, Weight #2, and Weight #3 was placed on the wooden block.
   d. Impossible to say.

9. As the amount of weight placed on the wooden block became greater, the force of friction

   a. became greater.
   b. stayed the same.
   c. became less.
   d. impossible to say.

10. You pulled the wooden block from Point A to Point B with three different amounts of weight placed on the wooden block. With which amount of weight was the force of friction the smallest?

   a. Weight #1
   b. Weight #1 and Weight #2
   c. Weight #1, Weight #2, and Weight #3
   d. Impossible to say.

APPENDIX C

SELECTED TASK DEVELOPMENT REFERENCES

SELECTED TASK DEVELOPMENT REFERENCES

Blough, Glenn O. et al. Science Is Adventuring 6. Chicago, Ill.: Scott, Foresman, and Co., 1965.

Brown, William R. Handbook of Science Activities. Worthington, Ohio: Education Associates, Inc., 1974.

Buckman, Ernest et al. Probing the National World/1-Intermediate Science Curriculum Study. Morristown, N.J.: Silver Burdett Co., 1970.

Devito, Alfred. Creative Sciencing. Boston: Little, Brown and Co., 1976.

Diamond, Sheldon R. Fundamental Concepts of Modern Physics. New York: AMSCO School Publications, Inc., 1970.

Dull, Charles E. Modern Physics. New York: Holt, Rinehart and Winston, Inc., 1964.

Dunn, Lois E. Investigating Science with Children, Volume 4, Motion. Darien, Conn.: Teacher's Publishing Corp., 1964.

Elementary Science Guide K-7. Richmond, Va.: State Department of Education, 1972.

Laboratory Guide for Physics - Physical Science Curriculum Study. United States of America: D. C. Heath and Co., 1960.

MacCracken, Helen D. et al. Science Through Discovery 3. Syracuse, N.Y.: L. W. Singer Co., 1967.

Mallinson, George G. et al. Science: Understanding Your Environment. Morristown, N.Y.: Silver Burdett Co., 1972.

Nelson, Leslie W. Science Activities for Elementary Children. Dubuque, Iowa: William C. Brown Co., 1976.

Resource Units for Sixth Grade Science. Las Cruces, N.M.: Las Cruces School District, 1964.

Rockcastle, Verne N. and others. Elementary School Science Book 5. Menlo Park, Calif.: Addison-Wesley Publishing Co., 1972.

Science--A Process Approach--Commentary for Teachers. United States of America: American Association for the Advancement of Science, 1964.

Sears, Francis W. et al. College Physics. Menlo Park, Calif.: Addison-Wesley Co., 1975.

Smith, Herbert A. Modern Science Level Four. Palo Alto, Calif: Laidlaw Brothers, 1972.

Williams, George A. and others. Challenges to Science. New York: McGraw -Hill, 1973.

APPENDIX D

PILOT STUDY ITEM ANALYSES

TABLE 55

TEST ITEM ANALYSES

Test	Number of Items	Mean Item Difficulty	Mean Item Discrimination	KR20
Anxiety (A Scale)[a]	42	.59	.44	.88
Dependency[b]	45	.37	.24	.63
Dependency[c]	30	.32	.35	.71
Concrete Op[d]	30	.43	.37	.73
Know Pretest	11	.61	.44	.75[e]
Know Task 1	10	.13	.29	.62
Know Task 2	10	.31	.57	.71
Know Task 3	10	.56	.69	.81
Know Task 4	10	.22	.61	.88
Know Task 5	10	.11	.34	.72
Know Total	50	.26	.36	.88
Inferring	12	.35	.61	.77
Predicting	11	.36	.47	.36
Inter. Data	18	.37	.41	.71
Id. and Controlling Variables	9	.45	.56	.52
Process Total[f]	50	.38	.39	.86

[a]Anxiety Scale of the Children Manifest Anxiety Scale (CMAS)
[b]Dependence Proneness Scale
[c]Modified Dependence Proneness Scale
[d]Concrete Op: Ankney-Joyce Reasoning Test
[e]Calculated for 22 items using the Spearman-Brown Procedure
[f]Process Total: Test of Science Inquiry Skills

APPENDIX E

LETTERS

Department of Science and
Mathematics Education
283 Arps Hall, 1945 N. High Street
The Ohio State University
Columbus, Ohio 43210
May 26, 1977

Mr. Lee Russell
Mifflin School
Rural Route 11, Reed Road
Mansfield, Ohio 44903

Dear Mr. Russell, Mrs. Malainy, Mrs. Dille, Mr. Pfahler, Mr. Buzzard, and Students:

I am writing to assure each of you that I have not forgotten the high level of professionalism and cooperation that was extended to me at Mifflin School. My experiences at Mifflin were quite enjoyable and enlightening. I have analyzed the data. The results were informative but for the most part not statistically significant. As a result of your cooperation, I have improved the tests, the activities and my data analysis procedures. I am currently completing my final study data collection at a Columbus area elementary school. Copies of a complete report (i.e., pilot and final study) will be forwarded upon its completion. The time line for completion of the aforementioned report is late summer. At that time, copies will be sent to the central office and to Mifflin School. I apologize for the delay, but it is the best that I can do.

Once again I would like to thank each of you for the helpful, cooperative atmosphere at Mifflin. I have the highest regard for the administration, faculty and students at Mifflin.

Sincerely,

David J. Harmon

DJH:jh

cc: Bud Henderson

Faculty of Science and
Mathematics Education
283 Arps Hall, 1945 N. High Street
Columbus, Ohio 43210
March 14, 1977

Dear Parent:

This letter is to notify you that your son or daughter has been selected to participate in a research study and that scores on two personality tests (i.e., anxiety and dependency) will be included as part of the data. The fifth and sixth grade students will be asked to participate in five fifty-minute science activities. The science activities will relate to the complex notion of force. The objectives of the activities are: (1) to acquire a knowledge level understanding of force; and (2) to improve such science process skills as predicting, inferring, and interpreting data. To determine if the objectives have been met, the students will be given a knowledge and science processes posttest. The amount of written direction (i.e., teaching structure) is varied between groups of students. If your child is assigned to the most structured or highly teacher directed group, each step in each activity will be explained in detail. As teaching structure decreases, the student must assume more responsibility for learning. This research will aid teachers in tailoring subject matter to fit the special needs and capabilities of each learner and thereby make learning a more efficient and enjoyable experience for both teacher and student.

It should be noted that: (1) participation is on a volunteer basis; (2) science activities and tests are consistent with school procedures; and (3) total anonymity will be maintained with respect to name of students, test scores, and teachers. If you object (i.e., upon receiving this letter or at any time during the study) to your child's participation, or if you desire additional information, please contact your child's teacher, the school principal, or me. Thank you for your cooperation.

Yours truly,

David J. Harmon
Phone: (614) 422-4121

DJH: jh

Faculty of Science and
Mathematics Education
283 Arps Hall, 1945 N. High Street
The Ohio State University
Columbus, Ohio 43210
January 20, 1977

Dr. David S. Palermo
Department of Psychology
441 Moore Building
Pennsylvania State University
University Park, PA 16802

Dear Dr. Palermo:

I am requesting a copy of your instrument "Children's Manifest Anxiety Scale" and permission to use it as is or with modifications in my doctoral dissertation. In addition, I would appreciate: (1) scoring/weighting procedures; (2) reliability and validity information; and (3) other information needed for successful utilization with fifth grade subjects. The present effort is an aptitude-treatment-interaction study involving: (1) fifth grade subjects; (2) the personological variables of anxiety and dependency; (3) teaching structure as determined by varying degrees of teacher and/or student control within each of ten instructional tasks; (4) ten concepts from within the conceptual scheme-force; (5) inductive/discovery learning in that the concepts to be acquired will not be presented to the subjects prior to treatment; and (6) two measures of concept understanding (i.e., knowledge and science processes levels). If desired, I will be more than happy to return information ascertained in the present study concerning your instrument. Thank you for your cooperation.

Yours truly,

David J. Harmon

DJH:jh

The Ohio State University
Faculty of Science and
Mathematics Education
283 Arps Hall, 1945 N. High Street
Columbus, Ohio 43210
January 20, 1977

Dr. Charles D. Speilberger
Computer-Assisted Instruction Center
Florida State University
Tallahassee, Florida 32306

Dear Dr. Speilberger:

I am requesting a copy of your instrument entitled "State-Trait Anxiety Inventory" and permission to use it as is or with modifications in my doctoral dissertation. In addition, I would appreciate: (1) scoring/weighting procedures; (2) reliability and validity information; (3) your comments concerning the instrument's applicability with fifth grade subjects; and (4) suggestions of other instruments that are appropriate for use with upper elementary school students. The present effort is an aptitude-treatment-interaction study involving: (1) fifth grade subjects; (2) the personological variables of anxiety and dependency; (3) teaching structure as determined by varying degrees of teaching and/or student control within each of ten instructional tasks; (4) ten concepts from within the conceptual scheme--force; (5) inductive/discovery learning in that the concepts to be acquired will not be presented to the subjects prior to treatment; and (6) two measures of concept understanding (i.e., knowledge and science processes levels). If desired, I will be more than happy to return information ascertained in the present study concerning your instrument.

Thank you for your cooperation.

Yours truly,

David J. Harmon

DJH:jh

The Faculty of Science
and Mathematics Education
283 Arps Hall, 1945 N. High Street
The Ohio State University
Columbus, Ohio 43210
January 14, 1977

Dr. Paul H. Ankney
Churchland's Teachers College
Department of Elementary Education
P.O. Box 301
Doubleview, Western Australia 6018

Dear Dr. Ankney:

I am requesting a copy of your instrument developed as part of your dissertation designed to measure concrete operational reasoning entitled "Paper and Pencil Test" and permission to use it as is or with modifications in my doctoral dissertation. In addition, I would appreciate: (1) scoring/weighting procedures; (2) reliability and validity information; (3) other information needed for successful utilization with fifth grade subjects. The present effort is an aptitude-treatment-interaction study involving: (1) fifth grade subjects; (2) the personological variables of anxiety and dependency; (3) teaching structure as determined by varying degrees of teacher and/or student control within each of ten instructional tasks; (4) ten concepts from within the conceptual scheme--force; (5) inductive/discovery learning in that the concepts to be acquired will not be presented to the subjects prior to treatment; and (6) two measures of concept understanding (i.e., knowledge and science processes levels). If desired, I will be more than happy to return information ascertained in the present study concerning your instrument.

Thank you for your cooperation. Dr. Mayer sends his regards.

Yours truly,

David J. Harmon

DJH:jh

The Faculty of Science
and Mathematics Education
283 Arps Hall, 1945 N. High Street
The Ohio State University
Columbus, Ohio 43210
January 14, 1977

Dr. Lyle K. Joyce
Department of Physics and Earth Sciences
Central Connecticut State College
New Britain, Connecticut 06050

Dear Dr. Joyce:

I am requesting a copy of your instrument developed as part of your dissertation designed to measure concrete operational reasoning entitled "Paper and Pencil Test" and permission to use it as is or with modifications in my doctoral dissertation. In addition, I would appreciate: (1) scoring/weighting procedures; (2) reliability and validity information; (3) other information needed for successful utilization with fifth grade subjects. The present effort is an aptitude-treatment-interaction study involving: (1) fifth grade subjects; (2) the personological variables of anxiety and dependency; (3) teaching structure as determined by varying degrees of teacher and/or student control within each of ten instructional tasks; (4) ten concepts from within the conceptual scheme--force; (5) inductive/discovery learning in that the concepts to be acquired will not be presented to the subjects prior to treatment; and (6) two measures of concept understanding (i.e., knowledge and science processes levels). If desired, I will be more than happy to return information ascertained in the present study concerning your instrument. Thank you for your cooperation.

Yours truly,

David J. Harmon

DJH:jh

Faculty of Science and
Mathematics Education
283 Arps Hall, 1945 N. High Street
The Ohio State University
Columbus, Ohio 43210
January 5, 1977

Dr. Robert K. Crocker
Memorial University of Newfoundland
St. John's, Newfoundland,
Canada

Dear Dr. Crocker:

I am requesting a copy of a "Dependence Proneness Scale" based on a scale developed by Flanders and permission to use it as is or with modifications in my doctoral dissertation. The present effort is an aptitude-treatment-interaction study involving: (1) fifth grade subjects; (2) the personological variables of anxiety and dependency; (3) ten concepts from within the conceptual scheme--force; and (4) two measures of concept understanding. I have read your research aritcle presented in the Journal of Research in Science Teaching and found it quite informative. If additional information (validation of "Dependence Proneness Scale," treatment information, developmental and/or implementation problems, etc.) and/or reports are available, I would appreciate a copy of each. If desired, I will be more than happy to return information concerning the results of the present study when completed. Thank you for your cooperation.

Yours truly,

David J. Harmon

DJH:jh

Faculty of Science and
Mathematics Education
283 Arps Hall, 1945 N. High Street
The Ohio State University
Columbus, Ohio 43210
January 5, 1977

Dr. Ned Flanders
#1 Spyglass Hill
Oakland, California 94618

Dear Dr. Flanders:

I am requesting permission to use as is or modify your instrument entitled "Dependence Proneness Scale" in my doctoral dissertation. The present effort is an aptitude-treatment-interaction study involving: (1) fifth grade subjects; (2) the personological variables of anxiety and dependency; (3) teaching structure as determined by varying degrees of teacher and/or student control within each of ten instructional tasks; (4) ten concepts from within the conceptual scheme--force; (5) inductive/discovery learning in that the concepts to be acquired will not be presented to the subjects prior to treatment; and (6) two measures of concept understanding (i.e., knowledge and science processes levels). I would also appreciate a copy of the instrument as well as any information concerning reliability, validity, developmental or implementation problems. If desired, I will be more than happy to return information ascertained in the present study concerning your instrument. Thank you for your cooperation.

Yours truly,

David J. Harmon

DJH:jh

Faculty of Science and
Mathematics Education
283 Arps Hall, 1945 N. High Street
The Ohio State University
Columbus, Ohio 43210
January 5, 1977

Dr. Joseph W. Riley
221 West Sunnybrook
Royal Oak, Michigan 48073

Dear Dr. Riley:

I am requesting a copy of your instrument entitled "Test of Science Inquiry Skills" and permission to use it as is or with modifications in my doctoral dissertation. The present effort is an aptitude-treatment-interaction study involving: (1) fifth grade subjects; (2) the personological variables of anxiety and dependency; (3) teaching structure as determined by varying degrees of teacher and/or student control within each of ten instructional tasks; (4) ten concepts from within the conceptual scheme--force; (5) inductive/discovery learning in that the concepts to be acquired will not be presented to the subjects prior to treatment; and (6) two measures of concept understanding (i.e., knowledge and science processes levels). I would appreciate any information concerning reliability, validity, developmental and/or implementation problems. If desired, I will be more than happy to return information ascertained in the present study concerning your instrument. Thank you for your cooperation.

Yours truly,

David J. Harmon

DJH:jh

APPENDIX F

MANCOVA AND MANOVA TABLES, ADJUSTED, RAW MEANS AND STANDARD DEVIATIONS FOR PRETEST AND MAIN STUDY ANALYSES NOT INCLUDED IN THE TEXT

TABLE 56

ANXIETY BY DEPENDENCY ADJUSTED, RAW MEANS AND RAW STANDARD DEVIATIONS FOR PRETEST VARIABLES[a]

Personality		Variables						
		A	B	C	D	E	F	
High Anxiety	High Dependency	8.93	53.59	53.80	50.76	52.88	55.29	Adj. M
		9.57	55.14	54.71	52.71	54.14	56.71	Raw M
		5.47	6.99	7.59	8.40	6.41	7.89	SD
	Low Dependency	6.22	47.25	45.61	48.04	48.57	47.59	Adj. M
		5.00	44.29	43.86	44.29	46.14	44.86	Raw M
		5.42	7.52	8.80	5.99	9.58	8.32	SD
Low Anxiety	High Dependency	6.01	49.92	51.86	50.84	49.85	45.64	Adj. M
		6.86	51.86	53.00	53.29	51.43	47.43	Raw M
		4.91	11.48	10.46	9.23	12.34	10.53	SD
	Low Dependency	7.64	50.09	49.45	50.51	48.57	51.33	Adj. M
		7.43	49.57	49.14	49.86	48.14	50.86	Raw M
		6.01	12.76	11.98	14.53	11.52	11.36	SD

number of subjects = 28

[a]Pretest variables list: A, Knowledge Pretest; B, Process Total; C, Inferring; D, Predicting; E, Interpreting Data; F, Identifying and Controlling Variables

TABLE 57

RAW AND ADJUSTED MEANS FOR ANXIETY AND DEPENDENCY MAIN EFFECTS WITH PRETEST VARIABLES

Criteria	Personality				
	Anxiety		Dependency		
	High	Low	High	Low	
Know. Pretest	7.58	6.85	7.50	6.93	Adj. M
	7.27	7.14	8.21	6.21	Raw M
Process Total	50.42	50.00	51.76	48.67	Adj. M
	49.71	50.71	53.50	46.93	Raw M
Inferring	49.71	50.65	52.83	47.53	Adj. M
	49.29	51.07	53.86	46.50	Raw M
Predicting	49.40	50.68	50.80	49.27	Adj. M
	48.50	51.57	53.00	47.07	Raw M
Inter. Data	50.72	49.21	51.36	48.57	Adj. M
	50.14	49.79	52.79	47.14	Raw M
Id. Con. Var.	51.44	48.49	50.47	49.46	Adj. M
	50.79	49.14	52.07	47.86	Raw M

number of subjects = 28

TABLE 58

MANCOVA FOR TREATMENT BY ANXIETY BY DEPENDENCY WITH KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	.83	10.00	284.00	.600

Univariate F Tests

Variable	F (5, 143)	Mean Square	P Less Than
Knowledge Total	1.40	86.44	.227
Process Total	.85	50.63	.515

TABLE 59

MANCOVA FOR TREATMENT BY ANXIETY BY DEPENDENCY WITH FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.09	25.00	517.86	.343

Univariate F Tests

Variable	F (5, 143)	Mean Square	P Less Than
Know Task 1	1.21	93.50	.281
Know Task 2	2.23	174.99	.054
Know Task 3	.75	51.00	.588
Know Task 4	.45	40.04	.811
Know Task 5	1.30	109.61	.267

TABLE 60

MANCOVA FOR TREATMENT BY ANXIETY BY DEPENDENCY
WITH FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	.66	20.00	465.28	.868

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Inferring	.36	25.15	.875
Predicting	.88	61.83	.495
Inter. Data	1.19	80.44	.315
Id. Con. Var.	.54	41.20	.745

TABLE 61

MANOVA FOR TREATMENT BY ANXIETY BY DEPENDENCY
WITH KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	.82	10.00	286.00	.609

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Knowledge Total	1.36	121.52	.243
Process Total	1.00	88.35	.423

TABLE 62

MANOVA FOR TREATMENT BY ANXIETY BY DEPENDENCY
WITH FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.10	25.00	521.58	.332

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Know Task 1	1.77	158.82	.122
Know Task 2	2.08	196.62	.071
Know Task 3	.50	44.12	.775
Know Task 4	.47	47.00	.799
Know Task 5	1.51	144.48	.192

TABLE 63

MANOVA FOR TREATMENT BY ANXIETY BY DEPENDENCY
WITH FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	.70	20.00	468.59	.830

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Inferring	.44	40.40	.821
Predicting	1.00	91.65	.427
Inter. Data	1.49	137.69	.196
Id. Con. Var.	.47	41.53	.799

TABLE 64

ADJUSTED MEANS FOR TREATMENT BY ANXIETY BY DEPENDENCY WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES[a]

Factor[b]			Criteria									
A	D	T	A	B	C	D	E	F	G	H	I	J	K
1	1	A	52.75	51.52	54.38	53.78	50.55	50.26	49.74	50.20	45.34	53.47	47.54
1	1	B	57.17	56.13	57.42	59.35	46.35	58.92	58.62	58.52	54.95	60.13	54.36
1	1	C	54.42	53.66	55.07	51.65	51.67	55.53	54.52	55.30	53.71	53.50	52.64
1	1	D	45.53	46.90	45.47	46.06	49.45	45.73	51.11	52.65	49.79	49.52	51.74
1	1	E	42.19	41.68	45.98	47.06	42.31	42.45	46.36	47.24	47.10	44.86	49.33
1	1	F	52.09	54.83	53.10	47.37	49.45	55.31	55.75	55.86	56.13	53.19	55.85
1	2	A	53.70	49.80	52.39	56.61	53.98	49.12	49.92	46.58	51.03	51.85	49.31
1	2	B	50.49	51.71	51.87	47.76	50.51	50.65	50.00	52.28	48.87	48.38	50.97
1	2	C	47.07	50.85	43.69	45.08	50.91	47.20	48.29	47.71	47.84	49.46	48.88
1	2	D	50.87	49.17	51.04	50.34	52.86	49.14	48.78	49.13	49.71	48.78	46.46
1	2	E	49.72	49.22	50.24	48.04	50.81	50.94	48.80	47.88	46.18	52.30	48.14
1	2	F	44.95	40.40	46.30	46.15	50.62	44.46	44.43	44.30	47.77	46.19	42.30
2	1	A	47.07	45.50	49.75	45.25	47.91	50.06	46.08	44.35	47.17	48.56	46.70
2	1	B	50.34	50.08	42.36	56.21	51.80	50.94	52.19	50.06	48.92	54.06	54.51
2	1	C	48.17	49.90	44.57	50.49	47.63	48.92	44.04	45.38	43.10	45.13	45.36
2	1	D	49.05	53.32	50.35	45.61	47.74	51.88	52.00	52.89	53.77	49.04	53.22
2	1	E	47.31	49.61	46.99	47.12	50.26	47.28	50.67	48.69	53.36	50.35	50.44
2	1	F	49.24	47.90	54.19	47.78	47.30	48.59	50.53	52.50	50.50	47.94	51.88
2	2	A	47.88	49.17	46.72	51.66	47.55	46.41	47.24	46.84	49.54	45.00	51.08
2	2	B	55.68	49.43	54.57	55.07	56.07	52.93	51.08	50.33	51.46	50.86	51.63
2	2	C	53.81	50.26	51.82	52.23	54.45	54.74	52.32	51.57	49.84	52.33	54.42
2	2	D	50.27	52.95	51.11	46.04	50.55	51.98	51.20	53.16	53.17	48.57	49.17
2	2	E	54.94	54.67	51.50	56.52	53.54	51.54	53.70	52.96	54.08	51.38	56.34
2	2	F	46.76	50.97	51.69	47.77	43.74	44.88	45.07	45.67	47.39	47.43	41.19

[a]Dependent variables list: A, Knowledge Total; B, Knowledge Task 1; C, Knowledge Task 2; D, Knowledge Task 3; E, Knowledge Task 4; F, Knowledge Task 5; G, Process Total; H, Inferring; I, Predicting; J, Interpreting Data; K, Identifying and Controlling Variables

[b]Factor: First column 1 = High Anxiety and 2 = Low Anxiety; Second column 1 = High Dependency and 2 = Low Dependency; Third column A = maximal Teaching Structure and F = minimal Teaching Structure

TABLE 65

RAW MEANS AND STANDARD DEVIATIONS FOR TREATMENT BY ANXIETY BY DEPENDENCY WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES[a]

Factor[b]			Criteria										
A	D	T	A	B	C	D	E	F	G	H	I	J	K	
1	1	A	53.00	51.71	54.57	54.00	50.71	50.43	50.00	50.43	45.57	53.71	47.71	M
			8.83	9.86	8.42	10.54	7.65	10.29	8.52	9.27	8.83	4.62	7.30	SD
1	1	B	56.43	55.57	56.86	58.71	45.86	58.43	57.86	57.86	54.29	59.43	52.86	M
			6.43	2.44	7.86	12.19	14.86	1.51	9.17	6.72	8.77	9.61	9.42	SD
1	1	C	56.00	54.86	56.29	53.00	52.71	56.57	56.14	56.71	53.14	55.00	53.71	M
			7.85	2.67	7.83	11.39	9.86	3.46	6.28	6.40	7.15	10.39	4.03	SD
1	1	D	45.29	46.71	45.29	45.86	49.29	45.57	50.86	52.43	49.57	49.29	51.57	M
			7.93	5.44	11.04	6.04	7.39	12.30	9.96	8.18	11.10	10.03	10.66	SD
1	1	E	41.29	41.00	45.29	46.29	41.71	41.86	45.43	46.43	46.29	44.00	48.71	M
			8.60	17.19	6.05	4.69	8.02	10.42	7.25	7.83	4.42	9.02	9.73	SD
1	1	F	54.00	56.29	54.57	49.00	50.71	56.57	57.71	57.57	57.86	55.00	57.14	M
			8.27	1.89	8.73	10.42	12.51	4.89	7.02	9.41	5.79	5.10	9.51	SD
1	2	A	51.14	47.86	50.43	54.43	52.29	47.43	47.29	44.29	48.71	49.43	47.57	M
			12.18	13.26	8.77	10.66	8.85	11.24	11.86	13.23	11.25	10.94	11.07	SD
1	2	B	48.43	50.14	50.29	46.00	49.14	49.29	47.86	50.43	47.00	46.43	49.57	M
			10.10	11.84	10.50	8.54	11.75	12.67	8.24	6.53	10.88	8.30	9.59	SD
1	2	C	49.14	52.43	45.29	46.86	52.29	48.57	50.43	49.57	49.71	51.43	50.29	M
			8.86	4.93	9.20	8.61	7.41	10.95	11.82	10.64	10.53	10.36	12.57	SD
1	2	D	49.14	47.86	49.71	48.86	51.71	48.00	47.00	47.57	48.14	47.14	45.29	M
			11.67	11.84	9.21	10.81	8.69	11.49	11.72	10.11	10.14	12.85	8.83	SD
1	2	E	47.00	47.14	48.14	45.71	49.00	49.14	46.00	45.43	43.71	49.71	46.29	M
			9.17	13.51	9.16	6.24	11.33	8.93	7.68	10.69	7.25	5.12	9.57	SD
1	2	F	38.43	35.43	41.29	40.57	46.29	40.14	37.71	38.43	41.86	40.00	37.86	M
			10.86	15.53	11.51	3.65	10.94	11.68	7.25	7.85	9.97	7.12	6.36	SD
2	1	A	51.29	48.71	53.00	48.86	50.71	52.86	50.43	48.14	51.00	52.57	49.57	M
			12.53	11.10	9.07	11.57	11.74	9.35	11.09	12.12	12.95	8.85	10.34	SD
2	1	B	50.43	50.14	42.43	56.29	51.86	51.00	52.29	50.14	49.00	54.14	54.57	M
			10.00	9.75	7.46	9.34	11.04	10.12	8.44	7.20	12.91	8.01	5.94	SD
2	1	C	47.43	49.43	44.00	49.86	47.14	48.43	43.29	44.71	42.43	44.43	44.86	M
			12.93	9.59	12.12	11.14	11.98	9.54	12.84	14.02	12.71	11.79	9.75	SD
2	1	D	46.00	51.00	48.00	43.00	45.71	49.86	48.86	50.14	51.00	46.14	51.14	M
			7.92	7.75	11.96	3.16	13.49	7.52	8.47	7.20	7.96	10.02	10.27	SD
2	1	E	54.43	54.71	52.14	52.86	54.71	51.71	57.57	54.71	59.43	56.71	55.00	M
			9.00	4.27	14.85	11.80	5.56	12.23	9.55	10.16	9.83	7.78	11.26	SD

TABLE 65 (continued)

Factor[b]			Criteria										
A	D	T	A	B	C	D	E	F	G	H	I	J	K	
2	1	F	49.00	47.71	54.00	47.57	47.14	48.43	50.29	52.29	50.29	47.71	51.71	M
			10.10	10.19	8.29	9.13	13.01	8.58	7.27	6.47	8.90	10.34	4.42	SD
2	2	A	50.29	51.00	48.57	53.71	49.14	48.00	49.71	49.00	51.71	47.29	52.71	M
			13.65	8.85	13.42	9.90	11.45	13.13	11.98	11.17	11.31	12.24	12.78	SD
2	2	B	56.43	50.00	55.14	55.71	56.57	53.43	51.86	51.00	52.14	51.57	52.14	M
			6.40	6.78	7.69	8.02	3.31	4.93	7.76	11.08	4.71	7.66	8.69	SD
2	2	C	55.71	51.71	53.29	53.86	55.71	56.00	54.29	53.29	51.57	54.14	55.71	M
			7.46	9.14	5.59	11.38	4.96	6.35	10.70	12.65	6.71	12.79	8.58	SD
2	2	D	47.71	51.00	49.14	43.86	48.86	50.29	48.57	50.86	50.86	46.14	47.43	M
			6.68	5.77	11.02	8.55	9.01	10.23	9.78	8.40	8.73	8.92	11.41	SD
2	2	E	58.00	57.00	53.86	59.14	55.57	53.57	56.86	55.71	56.86	54.29	58.43	M
			5.69	00.00	11.87	5.24	5.35	7.61	4.14	5.06	8.57	4.07	5.83	SD
2	2	F	45.86	50.29	51.00	47.00	43.14	44.29	44.14	44.86	46.71	46.57	40.57	M
			7.82	8.48	4.00	9.36	9.79	13.57	11.41	10.67	12.39	12.59	11.13	SD

[a]Dependent variables list: A, Knowledge Total; B, Knowledge Task 1; C, Knowledge Task 2; D, Knowledge Task 3; E, Knowledge Task 4; F, Knowledge Task 5; G, Process Total; H, Inferring; I, Predicting; J, Interpreting Data; K, Identifying and Controlling Variables

[b]Factor: First column 1 = High Anxiety and 2 = Low Anxiety; Second column 1 = High Dependency and 2 = Low Dependency; Third column A = maximal Teaching Structure and F = minimal Teaching Structure

TABLE 66

MANCOVA FOR TREATMENT BY ANXIETY WITH
KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	1.05	10.00	284.00	.402

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Knowledge Total	1.48	91.08	.201
Process Total	1.22	72.60	.302

TABLE 67

MANCOVA FOR TREATMENT BY ANXIETY WITH
THE FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	.81	20.00	465.28	.702

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Inferring	1.06	73.94	.385
Predicting	1.83	128.67	.110
Inter. Data	.76	50.86	.584
Id. Con. Var.	.55	42.11	.736

TABLE 68

MANCOVA FOR TREATMENT BY DEPENDENCY
WITH THE FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.11	25.00	517.86	.325

Univariate F Tests			
Variable	F (5, 143)	Mean Square	P Less Than
Know Task 1	1.55	114.04	.179
Know Task 2	1.28	100.46	.275
Know Task 3	2.03	137.88	.078
Know Task 4	.46	40.57	.806
Know Task 5	1.79	150.94	.118

TABLE 69

MANOVA FOR TREATMENT BY ANXIETY WITH
KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	1.49	10.00	286.00	.142

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Knowledge Total	2.01	179.74	.080
Process Total	2.33	206.43	.046

TABLE 70

MANOVA FOR TREATMENT BY ANXIETY WITH
THE FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.59	25.00	521.58	.036

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Know Task 1	2.38	213.11	.041
Know Task 2	1.34	126.27	.252
Know Task 3	2.01	176.81	.081
Know Task 4	2.20	220.10	.058
Know Task 5	.88	84.58	.495

TABLE 71

MANOVA FOR TREATMENT BY ANXIETY WITH
THE FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	1.07	20.00	468.59	.380

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Inferring	1.76	161.10	.124
Predicting	3.02	280.36	.013
Inter. Data	1.48	136.08	.202
Id. Con. Var.	1.27	112.87	.279

TABLE 72

MANOVA FOR TREATMENT BY DEPENDENCY WITH KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	1.63	10.00	286.00	.096

Univariate F Tests

Variable	F (5, 144)	Mean Square	P Less Than
Knowledge Total	1.85	165.50	.106
Process Total	2.35	208.45	.044

TABLE 73

MANOVA FOR TREATMENT BY DEPENDENCY WITH THE FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.02	25.00	521.58	.438

Univariate F Tests

Variable	F (5, 144)	Mean Square	P Less Than
Know Task 1	1.55	139.15	.177
Know Task 2	1.53	144.79	.183
Know Task 3	1.28	112.80	.276
Know Task 4	.78	77.76	.568
Know Task 5	1.93	185.27	.093

TABLE 74

MANOVA FOR TREATMENT BY DEPENDENCY WITH
THE FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	1.54	20.00	468.59	.065

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Inferring	1.96	179.98	.089
Predicting	1.42	131.33	.222
Inter. Data	1.73	159.29	.132
Id. Con. Var.	3.64	323.01	.004

TABLE 75

MANOVA FOR ANXIETY BY DEPENDENCY WITH
KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	3.38	2.00	143.00	.037

Univariate F Tests			
Variable	F (1, 144)	Mean Square	P Less Than
Knowledge Total	4.75	424.34	.031
Process Total	6.49	575.72	.012

TABLE 76

MANOVA FOR ANXIETY BY DEPENDENCY WITH
THE FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	2.41	5.00	140.00	.039

Univariate F Tests			
Variable	F (1, 144)	Mean Square	P Less Than
Know Task 1	3.89	348.60	.050
Know Task 2	6.29	594.38	.013
Know Task 3	5.11	450.15	.025
Know Task 4	.01	1.68	.914
Know Task 5	2.76	265.01	.099

TABLE 77

MANOVA FOR ANXIETY BY DEPENDENCY WITH
THE FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	2.06	4.00	141.00	.089

Univariate F Tests			
Variable	F (1, 144)	Mean Square	P Less Than
Inferring	8.02	737.53	.005
Predicting	4.11	381.01	.045
Inter. Data	2.95	272.60	.088
Id. Con. Var.	4.03	357.30	.047

TABLE 78

ADJUSTED MEANS FOR TREATMENT (A-F) BY ANXIETY WITH SIX MAIN STUDY DEPENDENT VARIABLES[a]

Factor		Variables					
Anxiety	Treatment	A	B	C	D	E	F
High Anxiety	A	53.22	49.83	48.39	48.19	52.66	48.43
	B	53.83	54.30	55.40	51.91	54.26	52.17
	C	50.75	51.41	51.50	50.77	51.48	50.76
	D	48.20	49.94	50.89	49.75	49.15	49.10
	E	45.95	47.58	47.56	46.64	48.58	48.73
	F	48.52	50.09	50.08	51.95	49.69	49.07
Low Anxiety	A	47.48	46.66	45.59	48.36	46.78	48.89
	B	53.01	51.64	50.19	50.19	52.46	53.07
	C	50.99	48.18	48.47	46.47	48.73	49.89
	D	49.66	51.60	53.02	53.47	48.80	51.19
	E	51.33	52.19	50.82	53.72	50.86	53.39
	F	48.00	47.80	49.09	48.95	47.69	46.53

number of subjects per cell = 14

[a]Dependent variables list: A, Knowledge Total; B, Process Total; C, Inferring; D, Predicting; E, Interpreting Data; F, Identifying and Controlling Variables

TABLE 79

RAW MEANS FOR TREATMENT (A-F) BY ANXIETY WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES[a]

Factor[b]		Variables										
		A	B	C	D	E	F	G	H	I	J	K
1	A	52.07	49.79	52.50	54.21	51.50	48.93	48.64	47.36	47.14	51.57	47.64
1	B	52.43	52.86	53.57	52.36	47.50	53.86	52.86	54.14	50.64	52.93	51.21
1	C	52.57	53.64	50.79	49.93	52.50	52.57	53.29	53.14	52.43	53.21	52.00
1	D	47.21	47.29	47.50	47.36	50.50	46.79	48.93	50.00	48.86	48.21	48.43
1	E	44.14	44.07	46.71	46.00	45.36	45.50	45.71	45.93	45.00	46.86	47.50
1	F	46.21	45.86	47.93	44.79	48.50	48.36	47.71	48.00	49.86	47.50	47.50
2	A	50.79	49.86	50.79	51.29	49.93	50.43	50.07	48.57	51.36	49.93	51.14
2	B	53.43	50.07	48.79	56.00	54.21	52.21	52.07	50.57	50.57	52.86	53.36
2	C	51.57	50.57	48.64	51.86	51.43	52.21	48.79	49.00	47.00	49.29	50.29
2	D	46.86	51.00	48.57	43.43	47.29	50.07	48.71	50.50	50.93	46.14	49.29
2	E	56.21	55.86	53.00	56.00	55.14	52.64	57.21	55.21	58.14	55.50	56.71
2	F	47.43	49.00	52.50	47.29	45.14	46.36	47.21	48.57	48.43	47.14	46.14

number of subjects per cell = 14

[a]Dependent variables list: A, Knowledge Total; B, Knowledge Task 1; C, Knowledge Task 2; D, Knowledge Task 3; E, Knowledge Task 4; F, Knowledge Task 5; G, Process Total; H, Inferring; I, Predicting; J, Interpreting Data; K, Identifying and Controlling Variables

[b]Factor: First column 1 = High Anxiety and 2 = Low Anxiety; Second column A = maximal Teaching Structure and F = minimal Teaching Structure

TABLE 80

ADJUSTED MEANS FOR TREATMENT (A-F) BY DEPENDENCY WITH EIGHT MAIN STUDY DEPENDENT VARIABLES[a]

Factor [b]		Variables							
		A	B	C	D	E	F	G	H
1	A	48.51	52.06	49.51	49.23	50.16	47.27	46.26	51.02
1	B	53.10	49.89	57.78	49.07	54.93	54.29	51.94	57.09
1	C	51.82	49.82	51.07	49.65	52.22	50.34	48.41	49.32
1	D	50.11	47.91	45.84	48.59	48.80	52.77	51.78	49.28
1	E	45.65	46.48	47.09	46.29	44.87	47.96	50.23	47.60
1	F	51.37	53.65	47.57	48.38	51.95	54.18	53.32	50.57
2	A	49.49	49.56	54.14	50.77	47.76	46.71	50.28	48.43
2	B	50.57	53.22	51.42	53.29	51.79	51.30	50.16	49.62
2	C	50.56	47.76	48.65	52.68	50.97	49.64	48.84	50.90
2	D	51.06	51.08	48.19	51.71	50.56	51.14	51.44	48.68
2	E	51.94	50.87	52.28	52.17	51.24	50.42	50.13	51.84
2	F	45.69	49.00	46.96	47.18	44.67	44.98	47.58	46.81

number of subjects per cell = 14

[a]Dependent variables list: A, Knowledge Task 1; B, Knowledge Task 2; C, Knowledge Task 3; D, Knowledge Task 4; E, Knowledge Task 5; F, Inferring; G, Predicting; H, Interpreting Data

[b]Factor: First column 1 = High Dependency and 2 = Low Dependency; Second column A = maximal Teaching Structure and F = minimal Teaching Structure

TABLE 81

RAW MEANS FOR TREATMENT (A-F) BY DEPENDENCY WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES[a]

Factor[b]		Variables										
		A	B	C	D	E	F	G	H	I	J	K
1	A	52.14	50.21	53.79	51.43	50.71	51.64	50.21	49.29	48.29	53.14	48.64
1	B	53.43	52.86	49.64	57.50	48.86	54.71	55.07	54.00	51.64	56.79	53.71
1	C	51.71	52.14	50.14	51.43	49.93	52.50	49.71	50.71	48.79	49.71	49.29
1	D	45.64	48.86	46.64	44.43	47.50	47.71	49.86	51.29	50.29	47.71	51.36
1	E	47.86	47.86	48.71	49.57	48.21	46.79	51.50	50.57	52.86	50.36	51.86
1	F	51.50	52.00	54.29	48.29	48.93	52.50	54.00	54.93	54.07	51.36	54.43
2	A	50.71	49.43	49.50	54.07	50.71	47.71	48.50	46.64	50.21	48.36	50.14
2	B	52.43	50.07	52.71	50.86	52.86	51.36	49.86	50.71	49.57	49.00	50.86
2	C	52.43	52.07	49.29	50.36	54.00	52.29	52.36	51.43	50.64	52.79	53.00
2	D	48.43	49.43	49.43	46.36	50.29	49.14	47.79	49.21	49.50	46.64	46.36
2	E	52.50	52.07	51.00	52.43	52.29	51.36	51.43	50.57	50.29	52.00	52.36
2	F	42.14	42.86	46.14	43.79	44.71	42.21	40.93	41.64	44.21	43.29	39.21

number of subjects per cell = 14

[a]Dependent variables list: A, Knowledge Total; B, Knowledge Task 1; C, Knowledge Task 2; D, Knowledge Task 3; E, Knowledge Task 4; F, Knowledge Task 5; G, Process Total; H, Inferring; I, Predicting; J, Interpreting Data; K, Identifying and Controlling Variables

[b]Factor: First column 1 = High Dependency and 2 = Low Dependency; Second column A = maximal Teaching Structure and F = minimal Teaching Structure

TABLE 82

ADJUSTED MEANS FOR ANXIETY BY DEPENDENCY WITH FIVE MAIN STUDY DEPENDENT VARIABLES[a]

Personality		Variables				
		A	B	C	D	E
High Anxiety	High Dependency	50.79	48.29	51.37	51.17	52.44
	Low Dependency	48.53	51.62	48.59	48.57	49.50
Low Anxiety	High Dependency	49.40	48.78	49.61	49.47	49.18
	Low Dependency	51.24	50.98	50.41	50.91	49.26

number of subjects per cell = 42

[a]Dependent variables list: A, Knowledge Task 1; B, Knowledge Task 4; C, Knowledge Task 5; D, Predicting; E, Interpreting Data

TABLE 83

RAW MEANS FOR ANXIETY BY DEPENDENCY WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES[a]

Factor[b]		Variables										
A	D	A	B	C	D	E	F	G	H	I	J	K
1	1	51.00	51.02	52.14	51.14	48.50	51.57	53.00	53.57	51.45	52.74	51.95
1	2	47.21	46.81	47.52	47.07	50.12	47.10	46.05	45.95	46.52	47.36	46.14
2	1	49.76	50.29	48.93	49.74	49.55	50.38	50.45	50.02	50.52	50.29	51.14
2	2	52.33	51.83	51.83	52.21	51.50	50.93	50.91	50.79	51.62	50.00	51.17

number of subjects per cell = 42

[a]Dependent variable list: A, Knowledge Total; B, Knowledge Task 1; C, Knowledge Task 2; D, Knowledge Task 3; E, Knowledge Task 4; F, Knowledge Task 5; G, Process Total; H, Inferring; I, Predicting; J, Interpreting Data; K, Identifying and Controlling Variables

[b]Factor: First column 1 = High Anxiety and 2 = Low Anxiety; Second column 1 = High Dependency and 2 = Low Dependency

TABLE 84

MANCOVA FOR TREATMENT MAIN EFFECTS WITH KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	1.34	10.00	284.00	.211

Univariate F Tests

Variable	F (5, 143)	Mean Square	P Less Than
Knowledge Total	1.68	103.59	.143
Process Total	1.27	75.61	.279

TABLE 85

MANCOVA FOR TREATMENT MAIN EFFECTS WITH THE FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	1.10	20.00	465.28	.342

Univariate F Tests

Variable	F (5, 143)	Mean Square	P Less Than
Inferring	1.68	117.38	.142
Predicting	.68	47.34	.643
Inter. Data	1.17	79.15	.325
Id. Con. Var.	1.08	82.08	.376

TABLE 86

MANCOVA FOR ANXIETY MAIN EFFECTS WITH
KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.34	2.00	142.00	.710

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Knowledge Total	0.00	0.00	1.000
Process Total	.49	28.83	.487

TABLE 87

MANCOVA FOR ANXIETY MAIN EFFECTS WITH
FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.21	5.00	139.00	.959

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Know Task 1	.24	17.79	.624
Know Task 2	.46	36.20	.498
Know Task 3	.03	1.74	.873
Know Task 4	.01	.23	.959
Know Task 5	.01	.05	.980

TABLE 88

MANCOVA FOR ANXIETY MAIN EFFECTS WITH
THE FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.07	4.00	140.00	.376

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Inferring	.71	49.26	.402
Predicting	.06	4.22	.807
Inter. Data	1.83	123.59	.178
Id. Con. Var.	.33	24.94	.568

TABLE 89

MANCOVA FOR DEPENDENCY MAIN EFFECTS WITH
KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	2.62	2.00	142.00	.177

Univariate F Tests			
Variable	F(1, 143)	Mean Square	P Less Than
Knowledge Total	.50	30.79	.481
Process Total	2.08	123.32	.152

TABLE 90

MANCOVA FOR DEPENDENCY MAIN EFFECTS WITH FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.82	4.00	140.00	.513

Univariate F Tests			
Variable	F (1, 143)	Mean Square	P Less Than
Inferring	2.61	181.65	.109
Predicting	.20	13.86	.657
Inter. Data	1.25	84.47	.265
Id. Con. Var.	1.93	146.72	.167

TABLE 91

MANOVA FOR TREATMENT MAIN EFFECTS WITH KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 2	1.39	10.00	286.00	.186

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Knowledge Total	2.12	189.25	.066
Process Total	1.10	97.78	.362

TABLE 92

MANOVA FOR TREATMENT MAIN EFFECTS WITH
FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 5	1.22	25.00	521.58	.215

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Know Task 1	.87	78.20	.501
Know Task 2	.48	44.94	.794
Know Task 3	4.05	357.00	.002
Know Task 4	.92	92.14	.470
Know Task 5	1.48	142.02	.200

TABLE 93

MANOVA FOR TREATMENT MAIN EFFECTS WITH
FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 4	1.04	20.00	468.59	.409

Univariate F Tests			
Variable	F (5, 144)	Mean Square	P Less Than
Inferring	.86	79.15	.509
Predicting	.26	23.65	.937
Inter. Data	1.64	151.00	.154
Id. Con. Var.	1.43	127.05	.216

TABLE 94

MANOVA FOR ANXIETY MAIN EFFECTS WITH
KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.90	2.00	143.00	.411

Univariate F Tests

Variable	F (1, 144)	Mean Square	P Less Than
Knowledge Total	1.77	158.15	.185
Process Total	.63	56.01	.428

TABLE 95

MANOVA FOR ANXIETY MAIN EFFECTS WITH
FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	.61	5.00	140.00	.691

Univariate F Tests

Variable	F (1, 144)	Mean Square	P Less Than
Know Task 1	2.15	192.86	.144
Know Task 2	.13	12.60	.716
Know Task 3	1.66	146.72	.199
Know Task 4	.62	61.93	.433
Know Task 5	.76	73.34	.383

TABLE 96

MANOVA FOR ANXIETY MAIN EFFECTS WITH
FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.01	4.00	141.00	.403

Univariate F Tests

Variable	F (1, 144)	Mean Square	P Less Than
Inferring	.19	17.36	.665
Predicting	1.97	182.29	.163
Inter. Data	.01	.38	.949
Id. Con. Var.	2.10	186.48	.149

TABLE 97

MANOVA FOR DEPENDENCY MAIN EFFECTS WITH
KNOWLEDGE AND PROCESS TOTALS

Multivariate Tests of Significance Using Wilk's Lambda Criterion

Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	3.72	2.00	143.00	.027

Univariate F Tests

Variable	F (1, 144)	Mean Square	P Less Than
Knowledge Total	.17	15.48	.678
Process Total	5.00	443.62	.027

TABLE 98

MANOVA FOR DEPENDENCY MAIN EFFECTS WITH
FIVE KNOWLEDGE POSTTESTS

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.42	5.00	140.00	.220

Univariate F Tests			
Variable	F (1, 144)	Mean Square	P Less Than
Know Task 1	.83	74.67	.363
Know Task 2	.33	30.86	.569
Know Task 3	.30	26.72	.583
Know Task 4	1.34	133.93	.250
Know Task 5	1.69	162.05	.196

TABLE 99

MANOVA FOR DEPENDENCY MAIN EFFECTS WITH
FOUR PROCESS SUBSCALES

Multivariate Tests of Significance Using Wilk's Lambda Criterion				
Test of Roots	F	DFHYP	DFERR	P Less Than
1 through 1	1.51	4.00	141.00	.203

Univariate F Tests			
Variable	F (1, 144)	Mean Square	P Less Than
Inferring	5.37	493.71	.022
Predicting	1.66	154.29	.199
Inter. Data	3.65	337.16	.058
Id. Con. Var.	3.96	351.48	.048

TABLE 100

ADJUSTED MEANS FOR TREATMENT MAIN EFFECTS WITH TEN MAIN STUDY DEPENDENT VARIABLES[a]

Treatment	Variables									
	A	B	C	D	E	F	G	H	I	J
A	50.35	49.00	50.81	50.00	48.96	48.24	47.00	48.27	49.72	48.66
B	53.42	51.84	51.56	51.18	53.36	52.97	52.80	51.05	53.36	52.62
C	50.87	51.19	48.79	51.16	51.60	49.80	50.00	48.62	50.11	50.32
D	48.93	50.59	49.50	50.15	49.68	50.77	51.95	51.61	49.00	50.15
E	48.64	48.79	48.68	49.23	48.06	49.88	49.19	50.18	49.72	51.06
F	48.26	48.53	51.32	47.78	48.31	48.95	49.58	50.45	48.69	47.80

number of subjects per cell = 28

[a]Dependent variables list: A, Knowledge Total; B, Knowledge Task 1; C, Knowledge Task 2; D, Knowledge Task 4; E, Knowledge Task 5; F, Process Total; G, Inferring; H, Predicting; I, Interpreting Data; J, Identifying and Controlling Variables

TABLE 101

RAW MEANS FOR TREATMENT MAIN EFFECTS WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES[a]

Treatment	Variables										
	A	B	C	D	E	F	G	H	I	J	K
A	51.43	49.82	51.64	52.75	50.71	49.68	49.36	47.96	49.25	50.75	49.39
B	52.93	51.46	51.18	54.18	50.86	53.04	52.46	52.36	50.61	52.89	52.29
C	52.07	52.11	49.71	50.89	51.96	52.39	51.04	51.07	49.71	51.25	51.14
D	47.04	49.14	48.04	45.39	48.89	48.43	48.82	50.25	49.89	47.18	48.86
E	50.18	49.96	49.86	51.00	50.25	49.07	51.46	50.57	51.57	51.18	52.11
F	46.82	47.43	50.21	46.04	46.82	47.36	47.46	48.29	49.14	47.32	46.82

number of subjects per cell = 28

[a]Dependent variables list: A, Knowledge Total; B, Knowledge Task 1; C, Knowledge Task 2; D, Knowledge Task 3; E, Knowledge Task 4; F, Knowledge Task 5; G, Process Total; H, Inferring; I, Predicting; J, Interpreting Data; K, Identifying and Controlling Variables

TABLE 102

ADJUSTED MEANS FOR ANXIETY MAIN EFFECTS WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES

Variables	Anxiety	
	High	Low
Know Total	50.08	50.08
Know Task 1	49.66	50.32
Know Task 2	50.58	49.63
Know Task 3	49.94	50.15
Know Task 4	50.00	49.88
Know Task 5	49.98	50.01
Process Total	50.52	49.68
Inferring	50.64	49.53
Predicting	49.67	50.19
Inter. Data	50.97	49.22
Id. Con. Var.	49.71	50.49

number of subjects per cell = 84

TABLE 103

RAW MEANS FOR ANXIETY MAIN EFFECTS WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES

Variables	Anxiety	
	High	Low
Know Total	49.11	51.05
Know Task 1	48.92	51.06
Know Task 2	49.83	51.38
Know Task 3	49.11	50.98
Know Task 4	49.31	50.52
Know Task 5	49.33	50.66
Process Total	49.52	50.68
Inferring	49.76	50.41
Predicting	49.00	51.07
Inter. Data	50.05	50.14
Id. Con. Var.	49.05	51.16

number of subjects per cell = 84

TABLE 104

ADJUSTED MEANS FOR DEPENDENCY MAIN EFFECTS WITH TEN MAIN STUDY DEPENDENT VARIABLES

Variables	Dependency	
	High	Low
Know Total	49.64	50.51
Know Task 1	50.09	49.88
Know Task 2	49.97	50.25
Know Task 3	49.81	50.27
Know Task 5	50.49	49.50
Process Total	50.97	49.24
Inferring	51.14	49.03
Predicting	50.32	49.74
Inter. Data	50.81	49.38
Id. Con. Var.	51.05	49.16

number of subjects per cell = 84

TABLE 105

RAW MEANS FOR DEPENDENCY MAIN EFFECTS WITH THE ELEVEN MAIN STUDY DEPENDENT VARIABLES

Variables	Dependency	
	High	Low
Know Total	50.38	49.77
Know Task 1	50.66	49.32
Know Task 2	50.54	49.68
Know Task 3	50.44	49.64
Know Task 4	49.02	50.81
Know Task 5	50.98	49.01
Process Total	51.73	48.48
Inferring	51.80	48.37
Predicting	50.99	49.07
Inter. Data	51.51	48.68
Id. Con. Var.	51.55	48.66

number of subjects per cell = 84